Chapter IV.

The Effect of Supplemental Row Cultivation on Soil Erosion and the Agronomic Performance of Conservation Tillage Flue-cured Tobacco

Abstract

Producer acceptance of conservation tillage for flue-cured tobacco production has been low since practice introduction in the late 1960's. Yield reduction, tobacco quality issues, unacceptable weed control, and inadequate transplanting equipment limited adoption and substantiated the need for additional investigation. The recent developments of a revolutionary herbicide and an improved transplanter have renewed interest in conservation tillage for tobacco production in the piedmont region of Virginia and North Carolina.

A three-year study was conducted to evaluate soil erosion and the agronomic characteristics of flue-cured tobacco produced using five conservation tillage production systems. Row cultivation was investigated at application frequencies of zero, one (layby only), two (early plus layby, and late plus layby), or three (early plus late plus layby) and comparison made to conventional tillage receiving four cultivations. Conservation tillage, without supplemental row cultivation, reduced soil erosion 92 percent compared to conventional tillage. Row cultivation did not significantly increase conservation tillage system soil erosion. The yield of conservation tillage produced tobacco was significantly increased with supplemental row cultivation. One, two, and three cultivations increased yield 18, 28, and 31 percent, respectively. The yield of conservation tillage tobacco receiving at least two cultivations was similar to

conventional tillage. Quality of the cultivated conservation tillage tobacco was similar to conventional tillage.

Introduction

The production of flue-cured tobacco using conservation tillage techniques has been limited primarily to research studies and small plantings since introduction in the late 1960's by Moschler *et al.* (1971). Yield reduction, poor transplant stand and limited weed control options served as obstacles that limited widespread producer acceptance of the production practice.

Conventional tobacco production relies on multiple tillage operations prior to crop transplanting for preparation of the planting surface and subsequent row cultivation for both weed control and modification of soil surface characteristics. This frequent soil disturbance leaves the soil prone to erosion by destroying soil structure and accelerating the degradation of cover crop residues. Although soil erosion resulting from conventional tillage culture is excessive (Wood and Worsham 1986), the high income generated from tobacco sales reduces the impact of this long-term issue. A recent decrease in tobacco farm number, increase in tobacco farm size, and an increased environmental awareness has led to the questioning of long-term conventional tobacco production sustainability.

Soil conservation practices associated with tobacco production rely primarily on crop rotation and/or installation of conservation structures for soil erosion reduction. Conservation structures are expensive to install, remove land from production, and interfere with maneuverability of multiple row equipment. Although effective for reducing soil erosion, these structures can be prohibitive to many farm operations. An attractive alternative to the use of these practices is conservation tillage. Conservation tillage offers the opportunity for these farm operations to decrease crop rotation length and utilize highly erodible cropland for tobacco production while maintaining reducing soil erosion.

Conservation tillage tobacco production was first discussed by Moschler *et al.* (1971) following the widespread adoption of no-tillage techniques for food crop production. Unacceptable tobacco yield reductions were attributed to poor soil-root contact and a deleterious effect of reduced soil temperature. Subsequent researchers observed similar yield reductions (Link 1984; Shilling et al. 1986; Wood and Worsham 1986; Wiepke et al. 1988) attributed to transplanter malfunction, weed competition and the presence of a stale or old seedbed. Researchers indicated the need for further investigation before widespread producer adoption of conservation tillage. A recent development in improved transplanter technology, the Subsurface Tiller Transplanter (SST-T) by Morse *et al.* (1993), combined with the availability of newer herbicides for weed control, offered the potential of increasing the yield of conservation tillage tobacco.

In an effort to examine the impact of these developments, a three-year research study was implemented at the Virginia Tech Southern Piedmont Agricultural Research and Extension Center in Blackstone, Virginia. Row cultivation was added to this study to improve seedbed aeration, weed control and modification of soil surface characteristics. In addition, row cultivation reduces plant lodging and ground sucker formation by building a row-ridge around the base of tobacco plants.

The objectives of this study were to:

1. evaluate the effect of row cultivation treatment on soil erosion, tobacco yield and tobacco quality of five conservation tillage flue-cured tobacco production systems and conventional tillage.
2. determine the particle size composition of collected soil erosion.

Materials and Methods

Field experiments were conducted at the Virginia Tech, Southern Piedmont Agricultural Research and Extension Center near Blackstone, Virginia in 1995, 1996 and 1997 on an eroded Mayodan sandy loam soil (Typic Hapludult, fine loamy, siliceous, thermic) with a slope of approximately 5 percent. The plow layer of this soil consisted of approximately 60 percent sand, 30 percent silt and 10 percent clay. The sand composition was approximately 5, 15, 15, 15, and 10 percent very coarse, coarse, medium, fine and very fine particles, respectively. Six tillage treatments were replicated four times and evaluated in a randomized complete block design. Treatments examined the transplanting of flue-cured tobacco (*Nicotinia tabacum L.*) into a herbicide killed rye cover crop and the subsequent effect of row cultivation on soil erosion and tobacco agronomic characteristics. Conventional tillage (Treatment T1), cultivated four times (at fertilizer sidedress, early, late and layby), was compared to five conservation tillage production systems receiving cultivation as described below:

	Timing of Cultivation		
Treatment	early	late	layby
T2	X	X	X
T3	X	--	X
T4	--	X	X
T5	--	--	X
T6	--	no cultivation	--

The cultivation designations of early, late, and layby describe the relative time of cultivation after tobacco transplanting (Appendix B). Both the early and late cultivation involve a light stirring of the soil to improve aeration and control weeds. Conversely, the layby cultivation involves intensive soil disturbance to form a row-ridge around plants before they become too tall for additional cultivation.

Research plots in all years were 16 feet wide, 40 feet long and composed of four bedded rows. Plot preparation began in late October prior to each year's study with moldboard plowing, disking, subsoil ripping and bedding. Prior to cover crop seeding, bed tops were leveled to a height of approximately 8 inches. Rye (*Secale cereale* var. *Abruzzi*) was broadcast seeded at a rate of 3 bushels per acre and 500 lbs. per acre 5-10-10 ($N:P_2O_5:K_2O$) fertilizer broadcast to enhance rye growth. Glyphosate (Roundup^{TM}) was applied at the rate of 3 lbs. a.i. per acre in mid-April of each year to kill the rye cover crop. Supplemental weed control was achieved using napropamide (Devrinol^{TM}) applied to all plots at 1.5 lb. a.i. per acre immediately following layby cultivation in 1995 and

1996. The herbicide program was modified for 1997 following the commercial release of sulfentrazone (Spartan™). Both clomozone (Command™) at 1.0 lb. a.i. per acre and sulfentrazone (Spartan™) at 0.3125 lb. a.i. per acre were broadcast applied prior to tobacco transplanting in a tankmix with glyphosate (Roundup™).

Flue-cured tobacco, variety K-326, was transplanted into the rye cover crop using a two-row Subsurface Tiller Transplanter™ (B and B No-till, Laurel Fork, VA; Morse *et al.* 1993) equipped with Lannen™ model RT-2 carousel transplanter units (Lannen Plant Systems, 27820 Iso-Vimma Finland). Transplanted plant population was approximately 6000 plants per acre. Center rows of each plot were bedded, planted, fertilized and cultivated together to insure uniform row spacing within the soil collection area. All rows within a given replication were planted in the same direction to produce a similar pattern of residue and soil surface disturbance. Imidacloprid (Admire™) was applied at 0.09 lbs. a.i. per acre for flea beetle and aphid control along with 10 pounds per acre 12-48-8 ($N:P_2O_5:K_2O$) Miller (Miller Chemical and Fertilizer Corp., Hanover, PA) Supreme starter fertilizer in the transplant water. A complete tobacco grade fertilizer, 6-12-18 ($N:P_2O_5:K_2O$), was knifed in two bands at a rate of 700 pounds per acre approximately 6 inches from transplants using Yetter fertilizer coulters (Yetter Manufacturing Company, Colchester, IL.). Additional sidedress fertilizer consisting of 280 pounds per acre 15-0-14 ($N:P_2O_5:K_2O$) was applied in a similar fashion approximately 3 weeks after transplanting using a Cole fertilizer applicator equipped with narrow cultivator feet. Remedial insect and sucker control practices were consistent with Virginia Cooperative Extension recommendations (Reed *et al.*, 1996).

Tobacco requires approximately 1 inch of water each week during the period from layby to topping for optimal growth (Reed *et al.*, 1996). Due to rainfall deficits during this period, tobacco was irrigated twice in 1996 using traveling guns and once in 1997 using stationary sprinklers to aid tobacco growth. Normal irrigation practices at the Southern Piedmont Agricultural Research and Extension Center include an approximate water output of ¼ inch per hour. For this study, a water output of ½ inch per hour was used to accelerate soil erosion. Approximately one inch of irrigation water was applied on June 30 in 1996 while two inches were applied on July 10 in 1996 and July 9 in 1997.

A KMC™ (Kelley Manufacturing Company, Tifton, GA) two-row rolling spider cultivator was used for row cultivation. The center rows of each plot were cultivated simultaneously and all cultivation was applied going down slope. This direction was chosen to minimize soil collection system disturbance (Chapter III).

The percent soil surface residue cover was measured using the line-transect method described by Sloneker and Moldenhauer (1977) and recommended by Laflen *et al.* (1981). Measurements were made on the row-ridge side, between the third and fourth row of each plot, approximately 5 inches from plants at 8 days following layby cultivation during 1996 and 1997. Row-ridge sides were chosen for measurement due to plant interference with a diagonal placement of the tape.

The effect of treatment on tobacco growth was quantified using a calculation of leaf area. The length and width of all leaves were measured on two plants per plot in 1996 and 1997 throughout the growing season. Repeated measurements were made using the same plants on a 10 to 14-day interval. Leaf area (Suggs *et al.*, 1964) was calculated as:

$$\text{Leaf Area} = \text{length} \times \text{width} \times 0.6534. \qquad (1)$$

A comparison of the upper-stalk leaf development was made using the leaf area of the third leaf from the plant apex determined on the last observation date each year.

In addition, the treatment effect on crop development was compared using the number of days to flower. Field bloom counts were taken on a two-day interval following the first observation of early button formation and continued until the completion of topping. The number of days to flower was determined as the observation date on which at least 50 percent of plants were in flower.

Soil erosion was quantified in 1996 and 1997 from the area located between the second and third row of each plot (4 feet wide and 40 feet long) using the collection system described in Chapter III. Following significant rainfall events (greater than 0.5 inch), collected runoff water was pumped from collection boxes and sediment removed. Collected soil material was placed into 18 gallon plastic tubs lined with open 33 gallon black plastic bags and allowed to dry inside a greenhouse. After drying to a moisture content of approximately 10 percent, sediment was weighed and moisture samples taken for a correction to oven-dry basis (2 percent moisture). Rainfall data was recorded onsite using a Rainwise^{TM} model RGEL electronic recording rain gauge (Rainwise Inc., Bar Harbor, ME).

Particle size analysis of the collected soil material followed the procedure of Day *et al.* (1956) utilizing an ASTM No. 152H Bouyouces scale hydrometer for clay fraction

(< 0.002 mm) determination and a nest of ASTM # 18, 35, 60, 140 and 270 sieves for sand fraction determination. For comparison purposes, the weighted average percents of sand (very coarse, coarse, medium, fine, very fine), silt, and clay were calculated as:

$$\text{Weighted average \%} = \text{\% particle size fraction} \times \text{proportion of total erosion} \quad (2)$$

where:

$$\text{Proportion of total erosion} = \frac{\text{individual event erosion}}{\text{season total erosion}} \quad (3)$$

Water samples were obtained immediately prior to water removal from collection boxes for a determination of turbidity, nitrate, and solution phosphorus. A 125 mL Nalgene^{TM} plastic bottle was submerged in each collection box and immediately transported to the laboratory for refrigeration and subsequent processing. Orthophosphate (solution phosphorus) and turbidity were determined using the method of the United States Environmental Protection Agency (U.S. EPA 1974) and nitrate was determined by the method of Keeney and Nelson (1982) with an Orion 93-07 NO_3^- electrode.

Four sequential harvests according to tobacco maturity were performed each year on the second and third row of each plot. Plot weights and official USDA grades were recorded and tobacco yield, average price, value per acre and grade indices calculated. Grade index (Bowman *et al.* 1988) provides a quantitative evaluation of cured leaf quality, average price represents the season’s average auction price for the observed grades, and value per acre reflects the average gross revenue of cured leaf produced on an acre. Total alkaloids (Davis 1976) and reducing sugars (Horwirtz 1980) were analyzed from a core sample of cured leaf separated by harvest number.

Air-dry root weight, plant height, and stalk diameter were measured in 1996 and 1997 from six plants per plot immediately following harvest completion. Randomly sampled plants were physically removed using a shovel to minimize the breakage and loss of roots. Soil was washed from root systems by a gentle stirring action in a 18-gallon tub of water. Following soil removal, root systems were allowed to air dry before weighing. Stalks were cut at the soil surface junction and diameter, height and root weight determined.

Analysis of variance was performed using the PROC GLM procedure in SAS (SAS Institute, 1989) and treatment means separated using the LSD test. Linear contrasts were performed to compare soil erosion, particle size movement and yield among treatments. Soil particle size data was transformed prior to analysis using an arcsin transformation (Little and Hills 1978).

Results

Soil erosion

<u>Quantity.</u> Quantitative differences in soil erosion among treatments were observed in 1996 and 1997. Figure 4.1 illustrates the seasonal soil erosion collected in 1996 and 1997. The eleven and nine erosion collections (Appendix A) of the 1996 and 1997 tobacco growing seasons, respectively, are depicted by the separate bar segments comprising each respective treatment.

Seasonal soil erosion was significantly reduced by conservation tillage tobacco culture (1996, $\underline{P} = 0.0248$; 1997, $\underline{P} = 0.0001$). No significant increase in conservation tillage soil erosion was associated with an increased row cultivation frequency. One layby cultivation (T5) increased soil erosion 5 and 6 percent and two cultivations increased soil erosion 3 and 8 percent (T4), and 8 and 10 (T3) percent in 1996 and 1997, respectively. The most intensively cultivated conservation tillage system (T2), receiving three cultivations, increased soil erosion 9 and 11 percent compared to the least erosive treatment (T6) in 1996 and 1997, respectively.

The lack of an interaction between treatment and year ($\underline{P} = 1.0000$) allowed for a combined analysis of soil erosion using both years (Table 4.1). Conservation tillage significantly reduced soil erosion ($\underline{P} = 0.0004$) 82 to 92 percent compared to conventional tillage. Supplemental row cultivation did not significantly increase conservation tillage soil erosion. Soil erosion was increased 5, 7 and 9 percent by one, two and three cultivations, respectively.

Soil disturbance resulting from transplanter operation and installation of the soil collection system, combined with the lack of a plant canopy (Appendix C), contributed to soil erosion during the early growing season. The effect is most apparent in the first two collections of 1996 and the first collection of 1997 for the five conservation tillage production systems, but especially for treatment T6. The first two collections of 1996 contributed 72 percent and the first collection of 1997 contributed 58 percent of the total growing season soil erosion. Runoff water was channeled in the narrow subsurface tilled zone and a small gully formed. This gully formation occurred prior to row cultivation and was similar for all conservation tillage treatments.

Erosion due to irrigation was accounted for in the July 11 collection of 1996 and the July 15 collection of 1997. Irrigation did not increase soil erosion compared to natural storm events.

Linear contrasts revealed seasonal soil erosion was significantly reduced by conservation tillage culture in 1996 ($\underline{P}$ = 0.0040) and 1997 ($\underline{P}$ = 0.0001). Row cultivation did not increase conservation tillage soil erosion as evidenced by the lack of a significant difference among the cultivated conservation tillage systems (T2, T3, T4, and T5) and the non-cultivated system (T6) in 1996 ($\underline{P}$ = 0.2553) and 1997 ($\underline{P}$ = 0.0690).

Particle Size Distribution

The weighted average clay, silt, and sand composition of soil erosion (Figure 4.2) followed the same general trend in both 1996 and 1997. Clay (1996, $\underline{P}$ = 0.0753; 1997, $\underline{P}$ = 0.5109) and silt (1996, $\underline{P}$ = 0.8812; 1997, $\underline{P}$ = 0.7882) composition of erosion was not significantly affected in either year, but both increased as cultivation frequency increased.

The sand composition of soil erosion was significantly affected in 1997 (very coarse, $\underline{P}$ = 0.0105; coarse, $\underline{P}$ = 0.0229; medium, $\underline{P}$ = 0.0248; fine, $\underline{P}$ = 0.0178; very fine, $\underline{P}$ = 0.0633) but not 1996 (very coarse, $\underline{P}$ = 0.3835; coarse, $\underline{P}$ = 0.2708; medium, $\underline{P}$ = 0.2578; fine, $\underline{P}$ = 0.2525; very fine, $\underline{P}$ = 0.4534) (Figure 4.3). Very coarse sand composition was significantly increased by conventional tillage culture, but no significant differences existed among the conservation tillage system treatments. Simarily, coarse sand composition of sediment was significantly higher for conventional tillage compared to the cultivated conservation tillage systems (T2-T5), but not the non-cultivated conservation tillage system (T6). Medium sand composition of sediment resulting from conventional tillage tobacco culture was similar to the non-cultivated treatment system (T6) and the layby only treatment (T5), but significantly higher than the conservation tillage treatments receiving two cultivations (T3 and T4). Fine sand composition of conventional tillage erosion was significantly higher than treatment T4.

Linear contrast analysis of arcsin transformed values revealed the conservation tillage system receiving no supplemental row cultivation significantly increased coarse ($\underline{P}$ = 0.0068), medium ($\underline{P}$ = 0.0025), fine ($\underline{P}$ = 0.0012), and very fine sand ($\underline{P}$ = 0.0060) composition of sediment compared to the cultivated conservation tillage systems (T2 - T5) in 1997. Conventional tillage significantly increased the very coarse ($\underline{P}$ = 0.0001), coarse ($\underline{P}$ = 0.0017), medium ($\underline{P}$ = 0.0079), fine ($\underline{P}$ = 0.0087), and very fine sand ($\underline{P}$ = 0.0059) composition of sediment in 1997 and coarse sand ($\underline{P}$ = 0.0455) in 1996 compared to the cultivated conservation tillage treatments (T2-T5).

Chemistry of Runoff Water

Solution phosphorus (orthophosphate) (Table 4.2) was considerably reduced by conventional tillage tobacco culture in 1996 ($\underline{P}$ = 0.0036) and 1997 ($\underline{P}$ = 0.0001) compared to the non-cultivated conservation tillage system (T6). Row cultivation did not increase solution phosphorus levels of runoff water. Linear contrasts revealed solution phosphorus was significantly reduced by the non-cultivated conservation tillage production system (T6) in 1996 ($\underline{P}$ = 0.0213) but not 1997 ($\underline{P}$ = 0.9263)

Turbidity (Table 4.2), a measure of water cloudiness, was increased in 1996 (P = 0.0001) and 1997 (P = 0.0001) by conventional tillage compared to the conservation tillage system receiving no row cultivation (T6). Row cultivation did not increase turbidity, but linear contrasts revealed cultivated conservation tillage (T2, T3, T4, and T5) increased turbidity compared to no cultivation (T6) in 1996 (P = 0.0368) and 1997 (P = 0.0001).

Minimal nitrogen loss was observed for all treatments (< 1ppm) and supportive of observations made by Johnson *et al.* (1979) regarding a 99 percent nitrogen loss associated with sediment. Sediment nutrient concentration was not quantified as part of this study.

Agronomic Measures

Yield

Flue-cured tobacco yield was significantly affected by conservation tillage culture in all three years of agronomic data collection (Figure 4.4). The 1995 (P = 0.0450) and 1997 (P = 0.0136) tobacco yields were similar, but lower than those of 1996 (P = 0.0071). The highest yield in 1996 resulted from conventional tillage (T1), but the highest yield in 1995 and 1997 resulted from the most intensively cultivated conservation tillage treatment (T2). The lowest and second lowest yield in all years was observed for the conservation tillage systems receiving no or only one row cultivation, respectively. Conservation tillage tobacco yield was significantly reduced when row cultivation was withheld. The non-cultivated conservation tillage system (T6) yield was significantly reduced compared to conventional tillage and the conservation tillage systems receiving row cultivation (T2-T5) in 1995, 1996, and 1997. The average yield reduction due to conservation tillage with no supplemental row cultivation (T6) for the 3-year study was 28 percent compared to the conventional tillage production system (T1), and 18 percent compared to the lowest yielding cultivated conservation tillage production system (T5). Conventional tillage tobacco yield was similar to the cultivated conservation tillage systems (T2-T5) in 1995 and 1997, but significantly higher than the conservation tillage system receiving only layby cultivation (T5) in 1996. Conservation tillage tobacco yield was increased 18 percent by one cultivation (T5), 28 percent by two cultivations (T3 and T4), and 31 percent by three cultivations (T2).

Linear contrasts revealed the non-cultivated conservation tillage system (T6) significantly reduced tobacco yield compared to the cultivated conservation tillage systems (T2-T5) in 1995 ($\underline{P} = 0.0010$), 1996 ($\underline{P} = 0.0011$), and 1997 ($\underline{P} = 0.0012$). Conversely conventional tillage and treatments T2, T3, T4 and T5 were similar in the three years of agronomic data collection (1995, $\underline{P} = 0.8983$; 1996, $\underline{P} = 0.3481$; 1997, $\underline{P} = 0.9232$).

The lack of an interaction between treatment and year ($\underline{P} = 0.9026$) allowed for the combined analysis of yield across all three years (Table 4.1). Conservation tillage tobacco yield was similar to conventional tillage yield when a minimum of two cultivations (T2, T3, and T4) was used. Conservation tillage receiving no row cultivation (T6) and layby only (T5) cultivation significantly reduced tobacco yield. One cultivation (T5) increased yield 18 percent, two cultivations (T3 and T4) increased yield 28 percent and three cultivations increased tobacco yield 31 percent.

Measures of Cured Leaf Quality

Tobacco value (Figure 4.5) (1995, $\underline{P}$ = 0.5800; 1996, $\underline{P}$ = 0.0080; 1997, $\underline{P}$ = 0.0112) was largely a consequence of tobacco yield since the grade index and price of cured tobacco were not significantly affected (Table 4.3). Conservation tillage receiving no supplemental row cultivation (T6) exhibited the lowest value in all three years of study and the conservation tillage system receiving early, late and layby cultivation (T2) was highest in 1995 and 1997 and conventional tillage (T1) highest in 1996. The non-cultivated conservation tillage system (T6) significantly reduced tobacco value in 1995 and 1997, but was similar to the layby cultivated (T5) conservation tillage system in 1996.

Plant Growth Variables

Treatment effect on plant growth was apparent from plant leaf area determined throughout the growing season (Table 4.4), air-dry root weight, stalk diameter and stalk height (Table 4.6).

Leaf area was significantly reduced by the non-cultivated conservation tillage system (T6) in 1996 compared to conventional tillage (T1) and the conservation tillage systems T2, T3 and T5. Similarly, non-cultivated conservation tillage culture significantly reduced leaf area compared to conventional tillage (T1), treatment T2 and treatment T3, but not treatments T4 and T5 in 1997.

Upper stalk leaf development was similar for all treatments during 1996 and 1997. Although no significant treatment effects were observed in either year, the non-cultivated conservation tillage system (T6) consistently exhibited the lowest leaf area.

The number of days to flower (Table 4.5) was significantly affected in 1996, but not in 1995 and 1997. Conventional tillage was the earliest to flower while conservation tillage receiving no supplemental row cultivation (T6) was the latest in most years. Row cultivation decreased the number of days to flower as application frequency increased.

Stalk diameter

Stalk diameter (Table 4.6) was significantly affected in 1996 and 1997 by conservation tillage culture. Conservation tillage receiving no supplemental row cultivation (T6) displayed the smallest stalk diameter in both years while conventional tillage culture and treatment T3 displayed the largest stalk diameter in 1996 and 1997, respectively. Values observed for layby cultivated conservation tillage (T5) were significantly reduced compared to conventional tillage (T1), conservation tillage receiving early and layby cultivation (T3) and late and layby cultivation (T4), but were significantly higher than the non-cultivated conservation tillage system (T6) in 1996. Non-cultivated conservation tillage culture (T6) significantly reduced stalk diameter in 1997.

Plant height

Although significant differences in plant height (Table 4.6) were observed in 1997, plant height is a poor indicator of tobacco growth. Stalk height is a subjective measure dependent on the personal judgment involved in breaking the flower during topping and consequently setting plant height.

Air-dry root weight

Although the pattern of root weight differences among treatments were similar in all years of data collection, significant differences were only observed in 1996. Conventional tillage (T1) displayed the highest root weight in 1996 while the conservation tillage system receiving early, late and layby cultivation (T2) was highest in 1997. Root weight was significantly reduced by conservation tillage receiving only layby cultivation (T5) and no cultivation (T6). An increase in cultivation frequency increased conservation tillage tobacco root weight. Root weight was increased 41 percent by the early, late, and layby cultivation (T2), early and layby (T3) and late and layby (T4) cultivations compared to the non-cultivated conservation tillage system (T6) in 1996.

Chemical Constituents of the Cured Leaf

Total Alkaloids

The total alkaloid content of cured tobacco was significantly affected in 1995 and 1997 by the conservation tillage culture systems. Total alkaloid content (Table 4.7) was higher in 1995 and 1997 compared to 1996. Conventional tillage (T1) exhibited the highest total alkaloid content, while the non-cultivated conservation tillage system (T6) displayed the lowest content in all years. Conventional tillage significantly increased total alkaloids compared to the conservation tillage systems receiving early and layby cultivation (T3), layby cultivation (T5) and no cultivation (T6). The conservation tillage production system receiving early, late and layby cultivation (T2) displayed a significantly higher total alkaloid concentration compared to the conservation tillage systems receiving layby cultivation (T5) and no cultivation (T6). The values for conservation tillage receiving late and layby cultivation (T4) were significantly higher than the conservation tillage treatment receiving no cultivation (T6). During 1997, conventional culture values were similar to those observed for the conservation tillage system receiving early and layby cultivation (T3), but significantly higher than all other production systems. The non-cultivated conservation tillage system (T6) was significantly lower than conventional tillage (T1), conservation tillage receiving late and layby cultivations (T3), but similar to all other treatments.

Reducing Sugars

Percent reducing sugar concentration of cured tobacco was higher in 1996 compared to 1995 and 1997. Conventional tillage culture (T1) significantly reduced reducing sugars (Table 4.7) in 1997 compared to the most frequently cultivated conservation tillage system (T2) and the conservation tillage treatment receiving early and layby cultivation (T3). Although differences observed among treatments in 1995 and 1996 were not significant ($P>0.05$), an increased frequency of cultivation increased the level of reducing sugars.

Total alkaloids:Reducing sugars

Significant differences in the ratio of total alkaloids to reducing sugars (Table 4.6) were observed during 1997. The most frequently cultivated conservation tillage system (T2) exhibited a significantly higher ratio than conventional tillage (T1), conservation tillage receiving only layby cultivation (T5) and conservation tillage receiving no cultivation (T6). The ratio resulting from conventional tillage culture was the lowest in all years. The observed reducing sugar to alkaloid ratios of 1995 and 1997 were less than five and indicative of potential smoke quality problems (Tso 1990).

Residue Quantity

Soil surface residue following layby cultivation was significantly affected in 1996 (P=0.0001) and 1997 (P=0.0001) (Figure 4.6). Conservation tillage receiving no supplemental row cultivation (T6) significantly increased residue quantity each year while conventional tillage (T1) significantly reduced residue quantity compared to the other treatments. Soil surface residue resulting from treatment T5 was significantly higher than the quantity observed from the other cultivated conservation tillage treatments (T2, T3, and T4) in 1996 but similar to these treatments in 1997. Residue quantity decreased as the frequency of cultivation increased.

Weed Pressure

Weed populations were not quantified as part of this study, but visual observations indicate weed quantity decreased as row cultivation frequency increased. Conservation tillage, receiving no cultivation (T6), exhibited the greatest amount of weed growth in all years while conventional tillage (T1) displayed the lowest amount of weeds. Problematic weeds each year included large crabgrass (*Digitaria sanguinalis*), common ragweed (*Ambrosia artemisiifolia*), and carpetweed (*Mollugo verticillata*). Carpetweed and early season crabgrass were easily controlled with row cultivation, but late season growth posed problems. The use of clomozone and sulfentrazone significantly improved weed control in 1997.

Discussion

Conservation tillage offers great promise for both large and small acreage flue-cured tobacco producers farming highly erodible cropland in the Piedmont region of Virginia and North Carolina. Soil erosion losses associated with tobacco production (Wood and Worsham 1986) can be minimized without sacrificing tobacco yield and farm income. The previously described limitations to conservation tillage tobacco production can be negated using row cultivation as described in this study.

The present study expands upon and complements the previous investigations of conservation tillage tobacco production. Researchers (Moschler *et al.* 1971; Link 1984; Shilling *et al.* 1986; and Wood and Worsham, 1986) primarily compared conventional tillage to the non-cultivated conservation tillage production system, treatments T1 and T6 in the present study, respectively. Yield reductions of 9 to 18 percent indicated the need for additional investigation before a widespread acceptance of the production practice by producers. Higher yield reductions associated with treatment T6 in the present study, ranging from 24 to 33 percent, confirmed the need for a modification to the previously described conservation tillage tobacco production systems.

A key production system modification examined in this study included the use of row cultivation at varying times during the early portion of the growing season. Row cultivation increased tobacco yield without significantly increasing soil erosion. Other key improvements included the use of improved herbicides, the Subsurface Tiller Transplanter™ (SST-T) and improved fertilizer incorporation.

Concerns expressed by previous investigators regarding a phytotoxic effect of glyphosate treated residue on tobacco stand establishment (Chappell and Link 1977) were not confirmed in this study. Explanations include improved transplanter movement of residue out of direct contact with transplants. Although the rye cover crop biomass was approximately 2.5 tons per acre and cover crop height was approximately 5 feet in both years, it lodged heavily following glyphosate application. This lodging reduced the movement of residue onto adjacent rows during planting.

Although subsurface tiller performance was exceptional in creating a transplant trench, the subsoil was inadequately loosened. Root weight reductions indicate the inability of tobacco roots to expand outside of the transplanter tilled zone. Row cultivation increased root weight by shaking and loosening the stale soil to improve root penetration and rainfall infiltration. In addition, cultivation aided in plant resistance to lodging (Chapter V.) by forming a raised row-ridge around the base of tobacco plants.

A noticeable tobacco growth phenomenon was observed in all years of study resulting from conservation tillage. Tobacco stalks exhibited a growth to the side and then upwards. Possible explanations for this growth include soil settling in the subsurface tiller trench, an uneven soil-planting surface created by subsurface tiller enhanced soil buckling and a residue enhanced microclimate.

Natural residue degradation enhanced row cultivation between the early and layby application. Rolling cultivator function was adequate, but residue wrapped around cultivator components and hindered proper operation. Residue was physically removed from the cultivator spiders after each plot to alleviate this concern, but this would be prohibitive on a large farm operation. Specially designed cultivators for high residue situations such as the Sukup™ Model 9400 (Sukup Manufacturing Company, Sheffield IA) would reduce this residue clogging concern.

Yield differences between years were related to rainfall quantity (Table 4.8). Higher rainfall in 1996 increased tobacco yield across all treatments. The lowest yield (T6) in 1996 was higher than the highest yield (T2) in both 1995 and 1997. An adequate availability of water allows tobacco to utilize growth inputs for leaf development rather than root exploration of the soil.

Shilling *et al.* (1986) reported the increased suppression of conservation tillage tobacco yield during years with adequate rainfall. Yield reductions of approximately 25 percent were observed during the dry growing seasons of both 1995 and 1997, while a yield reduction of 33 percent was observed during the wet 1996 season. The moisture holding and soil surface protection advantages associated with a soil surface mulch cover are most pronounced during dry years. Mulch intercepts sunlight and slows the formation of a hard soil surface layer, but would slow soil drying and contribute to plant losses due to drowning during extremely wet growing conditions.

Although row cultivation exposes soil and breaks surface residue into finer fractions, tobacco yield was increased by an increased row cultivation frequency. The non-cultivated conservation tillage system (T6) exhibited the highest amount of residue throughout the growing season, yet exhibited the lowest yield. This indicates surface residue is effective in conserving moisture only if adequate moisture is available in the underlying soil profile.

Tobacco yield was reduced by the non-cultivated conservation tillage system (T6) by a sealing and compaction of the soil surface resulting from excessive rainfall (Table 4.8) following fall bed preparation. Rainfall accelerated the movement of smaller soil particles downward through the soil profile and enhanced the formation of a hard soil surface crust. The planting operation destroyed this surface crust and loosened the soil in the zone of the subsurface tiller, but reformation quickly resulted. Row cultivation again destroyed this crusted layer to allow increased water infiltration and easier root penetration during the early portion of the growing season. Consequently, the crusted layer reformed shortly after layby cultivation due to high intensity rain events (Appendix A) combined with high summer temperatures. This observation is typical of the tobacco producing soils in the Piedmont region of Virginia.

Root system development can be related to growing season weather conditions (Table 4.6). Root weight resulting from the wet 1996 growing season was considerably reduced compared to that of the dry 1997 season. During wet years, less plant energy is expended for root development. Short periods of dry weather, combined with reduced root systems, place undue stress on plants and can reduce plant performance and consequently reduce yield.

The increased total alkaloid concentration observed in the dry production seasons of 1995 and 1997 confirm the weather related nature of compound synthesis. An increased total alkaloid concentration is usually associated with dry growing conditions and coupled with low reducing sugar levels (Weybrew *et al.*, 1983). The effect of treatment on total alkaloid content exhibited a similar pattern to root weight. Total alkaloid content was highest in years with high root weights. This observation supports the report by Tso (1990) indicating tobacco alkaloids are synthesized in the plant root system and then translocated to leaves.

Soil erosion observations similar to those of Wood and Worsham (1986) indicate an enormous reduction in soil erosion associated with conservation tillage, and more importantly cultivated conservation tillage. Soil erosion is dependent on soil surface roughness, rainfall duration, rainfall intensity, site slope and slope length. The non-cultivated conservation tillage system (T6) reduced soil erosion the greatest due to an increased soil surface roughness related to increased cover crop residue mulch. Cover crop residues create a protective barrier for the soil surface that reduces rainfall energy and the dislodgment of soil particles from direct impact. Although row cultivation destroyed this protective residue barrier, a soil surface with enhanced roughness was created. Soil particle dislodgment during rainfall increased, but the roughened soil surface impeded water flow and enhanced water infiltration.

The increased solution phosphorus and reduced turbidity of the non-cultivated conservation tillage treatment (T6) during 1996 supports the literature. Minimal soil disturbance after transplanting limited the availability of loose soil particles for adsorbing phosphorus from solution. An additional source of phosphorus to the applied fertilizer is decomposing cover crop residue. Cultivation increased residue decomposition, but also increased residue exposure to soil particles which can subsequently bind phosphorus.

Cultivation treatment had minimal impact on tobacco yield and soil erosion, but both increased as the frequency of cultivation increased. The use of row cultivation at a frequency of early and layby appears to offer a trade-off between soil erosion, tobacco yield and operator labor. The layby cultivation appears deficient to consistently increase tobacco yield to an acceptable level whereas three cultivations require additional operator labor and associated equipment operating expenses. Cultivation at an early timing would provide the most efficient method of controlling small weeds and dislodging the hard soil surface crust to allow for increased water infiltration. A delay in first cultivation to the late timing would reduce weed control due to larger and more developed weeds.

The effect of leaf canopy development on soil erosion is evident throughout the growing season. During the first month of field production, leaf development is slow and the soil surface remains unprotected from rainfall impact. Leaf formation is rapid following layby cultivation and a protective barrier for bedsides is quickly formed. Leaf expansion after topping either concentrates rainfall down the plant stalk or into row middles. Often, bedsides remain dry following rain events due to this phenomenon. Sequential harvest subsequently reduces the amount of leaf protection offered the soil surface and bedsides.

Irrigation enhanced soil erosion was minimal in both years, although an excessive output of water was applied. The lack of an irrigation effect is related to the time of irrigation application. Irrigation was applied immediately after cultivation in both years while the soil surface was loose, rough, and extremely dry. Row cultivation destroyed the hard soil surface crust and allowed increased infiltration of applied water.

The increased sand composition of soil erosion for conventional tillage (T1) and the non-cultivated conservation tillage system (T6) is related to soil surface sealing and crust formation. Conventional tillage displayed a small amount of incorporated cover crop residue in the soil surface layer, but the non-cultivated conservation tillage system (T6) exhibited a hard, stale seedbed prepared during the previous fall. The incorporation of surface residue and light disturbance of the soil during row cultivation hindered formation of a hard surface soil layer in the cultivated conservation tillage systems. Clay movement decreased from plots exhibiting this crust formation due to a binding of clay and silt during the formation process. Crust formation created a hard surface conducive for the flow of water and the movement of larger sand particles. The increased loss of clay and silt observed from the cultivated conservation tillage systems resulted from a decreased binding of these particles. A decreased loss of sand observed with row cultivation resulted from the physical barrier created from the cut residue and from the formation of small ridges and valleys which slowed runoff water flow and allowed for the settling of these larger particles.

The impact of rainfall intensity and duration on soil erosion is clearly evident in both years (Appendix A), but most apparent in the collections of September 9 and September 16 during 1996. Erosion collected on September 9 resulted from Hurricane Fran, a long duration storm with high rainfall but relatively low intensity while the bulk of erosion on September 16 resulted from a high intensity thunderstorm of short duration. The quantity of rainfall measured during the first 5 hours of the latter storm was higher than the quantity measured from 50 hours of the Hurricane. Erosion measured on September 16 was much higher compared to values observed for Hurricane Fran. During Hurricane Fran, there was a small quantity of rainfall observed during the first 15 hours of collection which adequately wet and softened the soil surface before the deluge of rainfall observed from 35 to 50 hours. The majority of rainfall fell during the first 5 hours for the September 16 collection and erosion was much higher compared to that observed for the Hurricane.

Conservation tillage tobacco production, combined with multiple row cultivation, offers a viable method for reducing soil erosion and maintaining acceptable tobacco yield. Although advances in production technology were insufficient to overcome the yield reduction previously identified with conservation tillage tobacco culture, multiple row cultivation was sufficient to increase tobacco yield to an acceptable level.

Before a widespread adoption of conservation tillage culture, tobacco producers need to evaluate their individual operations and formulate a long-term farm operation plan. The majority of tobacco producers in the Southern Piedmont region of Virginia rely on either a one or two-year crop rotation to satisfy the conservation compliance provisions of the 1985 Farm Bill. The use of conservation tillage would allow these producers an opportunity to incorporate an additional year of tobacco into their rotation plan. Conservation tillage production would best work in the year following conventional tobacco production. Producers normally till their land following tobacco harvest to destroy tobacco stalks and root systems before seeding of the small grain cover crop. The formation of bedded rows could easily be incorporated into this tillage plan prior to the small grain seeding operation. The following rotation plan incorporates conservation tillage into a one year tobacco rotation:

Year 1 = Conventional tobacco, fall bedding and cover seeding

Year 2 = Conservation tillage tobacco

Year 3 = Grain or hay crop

Year 4 = Conventional tobacco

The rotation can be modified as follows for a producer using a two-year crop rotation:

Year 1 - Conventional Tobacco

Year 2 - Conventional tobacco, fall bedding and cover seeding

Year 3 – Conservation tillage tobacco

Year 4 – Grain or hay crop

Year 5 – Grain or hay crop

Year 6 – Conventional Tobacco

The use of conservation tillage for tobacco production following a grain or hay crop is discouraged due to variations in soil surface hardness and residue that would be alleviated with moldboard plowing, subsoil ripping and multiple discings.

Potential production problems warranting further investigation include nematode, black shank and granville wilt control. These production concerns are widespread in the Piedmont region of Virginia and control measures need to be evaluated for conservation tillage tobacco production. The use of strip-tillage, a more intensive and deeper tillage operation compared to the subsurface tiller operation, offers an opportunity for incorporation of effective chemicals and improved control of these diseases.

Producers need to consider herbicide use during the years of conventional tobacco production. Herbicide carryover from napropamide (Devrinol^{TM}) and especially clomozone (Command™) can stunt small grain and decrease stand. One of the most important components of a successful conservation tillage production system is an adequate quantity of cover crop residue.

Producers should minimize the acreage devoted to conservation tobacco production until experience with the production system is gained relative to their individual soil conditions. Producers need to consider the increased level of management required with conservation tillage tobacco production and realize that conservation tillage is not an answer, but simply a component to allow U.S. producers to become more competitive in the future.

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Table 4.1. Average yield and soil erosion of five conservation tillage flue-cured tobacco production systems and conventional tillage.

Treatment		Yield	Total soil erosion
no.	tillage system[1]	pounds per acre	tons per acre
T1	Conventional tillage	2756 a	17.70 a
T2	CT - early, late, and layby	2774 a	3.10 b
T3	CT – early and layby	2740 a	2.90 b
T4	CT - late and layby	2710 ab	2.31 b
T5	CT - layby only	2498 b	2.38 b
T6	CT - no cultivation	2124 c	1.45 b
	P-value	0.0001	0.0004
	CV	10.0	104.5
	LSD $_{(0.05)}$	227	4.99

[1] CT – Conservation tillage; early cultivation occurred at 14 days after transplanting (DAT) in 1995, 26 DAT in 1996 and 30 DAT in 1997; late cultivation was at 23 DAT in 1995, 33 DAT in 1996 and 38 DAT in 1997; and layby cultivation was at 35 DAT in 1995, 39 DAT in 1996 and 45 DAT in 1997.

Means within a column followed by the same letter are not significantly different.

Table 4.2. Solution phosphorus and turbidity of five conservation tillage flue-cured tobacco production systems and conventional tillage in 1996 and 1997.

Treatment		Solution phosphorus		Turbidity	
		1996	1997	1996	1997
no.	tillage system[1]	ppm		percent absorbency	
T1	Conventional tillage	0.16 b	0.04 c	0.14 a	0.28 a
T2	CT - early, late, and layby	0.15 b	0.08 a	0.11 ab	0.12 b
T3	CT – early and layby	0.15 b	0.09 a	0.05 c	0.11 b
T4	CT - late and layby	0.20 ab	0.07 b	0.07 bc	0.13 b
T5	CT - layby only	0.19 ab	0.08 a	0.04 c	0.13 b
T6	CT - no cultivation	0.24 a	0.08 a	0.03 c	0.03 c
	P-value	0.0036	0.0001	0.0001	0.0001
	CV	114.2	55.3	153.5	52.6
	LSD $_{(0.05)}$	0.08	0.03	0.04	0.05

[1] CT – Conservation tillage; early cultivation occurred at 14 days after transplanting (DAT) in 1995, 26 DAT in 1996 and 30 DAT in 1997; late cultivation was at 23 DAT in 1995, 33 DAT in 1996 and 38 DAT in 1997; and layby cultivation was at 35 DAT in 1995, 39 DAT in 1996 and 45 DAT in 1997.

Means within a column followed by the same letter are not significantly different.

Table 4.3. Grade index and market price of five conservation tillage flue-cured tobacco production systems and conventional tillage in 1995, 1996 and 1997.

Treatment		Grade index			Market price		
		1995	1996	1997	1995	1996	1997
no.	tillage system[1]	1-100			U.S. $ per pound		
T1	Conventional tillage	78.0	61.8	73.0	1.81	1.90	1.76
T2	CT - early, late, and layby	74.0	66.5	74.8	1.80	1.91	1.75
T3	CT – early and layby	76.0	73.0	75.0	1.80	1.90	1.75
T4	CT - late and layby	76.3	69.3	74.0	1.80	1.89	1.75
T5	CT - layby only	77.8	71.8	72.3	1.82	1.91	1.74
T6	CT - no cultivation	69.5	65.3	72.3	1.80	1.91	1.74
	P-value	0.2505	0.4179	0.2540	0.5545	0.4454	0.8487
	CV	9.9	13.4	2.7	0.9	0.8	1.2
	LSD $_{(0.05)}$	ns	ns	ns	ns	ns	ns

[1] CT – Conservation tillage; early cultivation occurred at 14 days after transplanting (DAT) in 1995, 26 DAT in 1996 and 30 DAT in 1997; late cultivation was at 23 DAT in 1995, 33 DAT in 1996 and 38 DAT in 1997; and layby cultivation was at 35 DAT in 1995, 39 DAT in 1996 and 45 DAT in 1997.

Table 4.4. Average total plant leaf area and area of the third leaf from plant apex of five conservation tillage flue-cured tobacco production systems and conventional tillage in 1996 and 1997.

Treatment		Total leaf area		One leaf area	
no.	tillage system[1]	1996	1997	1996	1997
		square centimeters		square centimeters	
T1	Conventional tillage	8,396 a	10,403 ab	1,684	1,131
T2	CT - early, late, and layby	8,171 a	11,039 a	1,702	1,293
T3	CT – early and layby	8,674 a	9,858 bc	1,580	1,241
T4	CT - late and layby	6,934 b	9,131 dc	1,776	1,257
T5	CT - layby only	7,998 a	8,944 de	1,701	1,141
T6	CT - no cultivation	6,912 b	8,899 de	1,420	1,107
	P-value	0.0001	0.0001	0.6679	0.1371
	CV	22.2	17.7	17.6	14.1
	LSD $_{(0.05)}$	702	1,352	ns	ns

[1] CT – Conservation tillage; early cultivation occurred at 14 days after transplanting (DAT) in 1995, 26 DAT in 1996 and 30 DAT in 1997; late cultivation was at 23 DAT in 1995, 33 DAT in 1996 and 38 DAT in 1997; and layby cultivation was at 35 DAT in 1995, 39 DAT in 1996 and 45 DAT in 1997.

Means within a column followed by the same letter are not significantly different.

Table 4.5. The number of days to flower of five conservation tillage flue-cured tobacco production systems and conventional tillage in 1995, 1996 and 1997.

Treatment		Days to flower		
		1995	1996	1997
no.	tillage system[1]		number	
T1	Conventional tillage	57.0	61.5 b	75.7
T2	CT - early, late, and layby	59.0	62.0 ab	76.5
T3	CT – early and layby	57.0	62.0 ab	75.3
T4	CT - late and layby	57.0	63.0 ab	75.3
T5	CT - layby only	57.0	63.5 a	76.5
T6	CT - no cultivation	59.0	62.5 ab	81.0
	P-value	0.2172	0.0001	0.2791
	CV	3.6	2.4	5.0
	LSD $_{(0.05)}$	ns	1.50	ns

[1] CT – Conservation tillage; early cultivation occurred at 14 days after transplanting (DAT) in 1995, 26 DAT in 1996 and 30 DAT in 1997; late cultivation was at 23 DAT in 1995, 33 DAT in 1996 and 38 DAT in 1997; and layby cultivation was at 35 DAT in 1995, 39 DAT in 1996 and 45 DAT in 1997.

Means within a column followed by the same letter are not significantly different.

Table 4.6. Air dry root weight, stalk diameter, and plant height of five conservation tillage flue-cured tobacco production systems and conventional tillage in 1996 and 1997.

Treatment		Air dry root weight		Stalk diameter		Plant height	
		1996	1997	1996	1997	1996	1997
no.	tillage system[1]	grams		millimeters		centimeters	
T1	Conventional tillage	115.00 a	181.00 a	32.44 a	25.27 a	85.00 a	74.63 a
T2	CT - early, late, and layby	105.00 a	190.00 a	30.62 ab	25.91 a	83.50 a	80.06 b
T3	CT – early and layby	105.00 a	179.00 a	31.48 a	26.10 a	82.13 a	79.29 b
T4	CT - late and layby	105.00 a	174.00 ab	31.00 a	25.49 a	82.08 a	79.58 b
T5	CT - layby only	87.00 b	168.00 ab	29.03 b	24.74 a	82.46 a	80.71 b
T6	CT - no cultivation	74.00 b	145.00 b	26.85 c	23.08 b	84.17 a	80.63 b
	P-value	0.0001	0.0002	0.0001	0.0001	0.0035	0.0001
	CV	29.9	32.1	11.0	9.9	7.7	6.7
	$LSD_{(0.05)}$	16.86	42.91	1.90	1.92	3.67	4.11

[1] CT – Conservation tillage; early cultivation occurred at 14 days after transplanting (DAT) in 1995, 26 DAT in 1996 and 30 DAT in 1997; late cultivation was at 23 DAT in 1995, 33 DAT in 1996 and 38 DAT in 1997; and layby cultivation was at 35 DAT in 1995, 39 DAT in 1996 and 45 DAT in 1997.

Means within a column followed by the same letter are not significantly different.

Table 4.7. Total alkaloid and reducing sugars content of five conservation tillage flue-cured tobacco production systems and conventional tillage in 1995, 1996 and 1997.

Treatment		Total Alkaloids			Reducing sugars			Ratio		
		1995	1996	1997	1995	1996	1997	1995	1996	1997
no.	tillage system[1]		percent			percent				
T1	Conventional tillage	3.11 a	2.39	4.04 a	9.63 b	13.39	10.34 c	3.11 a	5.99	2.56 c
T2	CT - early, late, and layby	3.02 ab	2.09	3.46 c	10.15 ab	16.52	13.33 a	3.37 a	7.97	3.85 a
T3	CT – early and layby	2.83 bcd	2.29	3.81 ab	11.13 ab	14.27	12.34 ab	3.94 ab	6.23	3.28 ab
T4	CT - late and layby	3.00 abc	2.22	3.65 bc	10.61 ab	13.31	11.82 abc	3.57 ab	6.05	3.25 bc
T5	CT - layby only	2.75 dc	2.10	3.62 bc	12.24 a	15.50	10.57 bc	4.50 b	7.51	2.92 bc
T6	CT - no cultivation	2.60 d	1.92	3.46 c	9.97 b	16.54	10.80 bc	3.91 ab	8.62	3.13 bc
	P-value	0.0111	0.2692	0.0046	0.0616	0.2806	0.0265	0.0436	0.3174	0.0433
	CV	6.0	11.1	4.6	13.3	14.1	10.3	17.5	23.3	13.4
	LSD $_{(0.05)}$	0.26	ns	0.13	2.13	ns	0.93	0.99	ns	0.33

[1] CT – Conservation tillage; early cultivation occurred at 14 days after transplanting (DAT) in 1995, 26 DAT in 1996 and 30 DAT in 1997; late cultivation was at 23 DAT in 1995, 33 DAT in 1996 and 38 DAT in 1997; and layby cultivation was at 35 DAT in 1995, 39 DAT in 1996 and 45 DAT in 1997.

Means within a column followed by the same letter are not significantly different.

Table 4.8. Monthly rainfall received between fall bed preparation and tobacco harvest completion in 1995, 1996 and 1997.

	Production year		
Month	1995	1996	1997
Cover crop seeding		inches	
November	3.72	3.30	4.64
December	0.81	1.48	4.21
January	4.46	3.35	2.43
February	1.68	2.64	3.67
March	3.09	3.58	3.29
April	2.13	4.04	5.75
May	3.56	3.88	0.52
Tobacco transplanting			
May	1.33	0.00	0.49
June	7.93	2.74	3.39
July	5.43	5.96	4.09
August	2.98	5.66	1.30
September	1.92	11.5	2.79
October	0.00	0.17	2.23
Harvest Completion			

Figure 4.1a-b. Seasonal soil erosion quantified in 1996 (a) and 1997 (b) resulting from five conservation tillage flue-cured tobacco production systems and conventional tillage. Treatment bars are comprised of 11 and 9 individual erosion observations for the 1996 and 1997 growing seasons, respectively. Treatment designations refer to conventional tillage (T1) and conservation tillage (T2-T6). Row cultivation was applied at early, late and layby (T2), early and layby (T3), late and layby (T4), layby (T5) and none (T6).

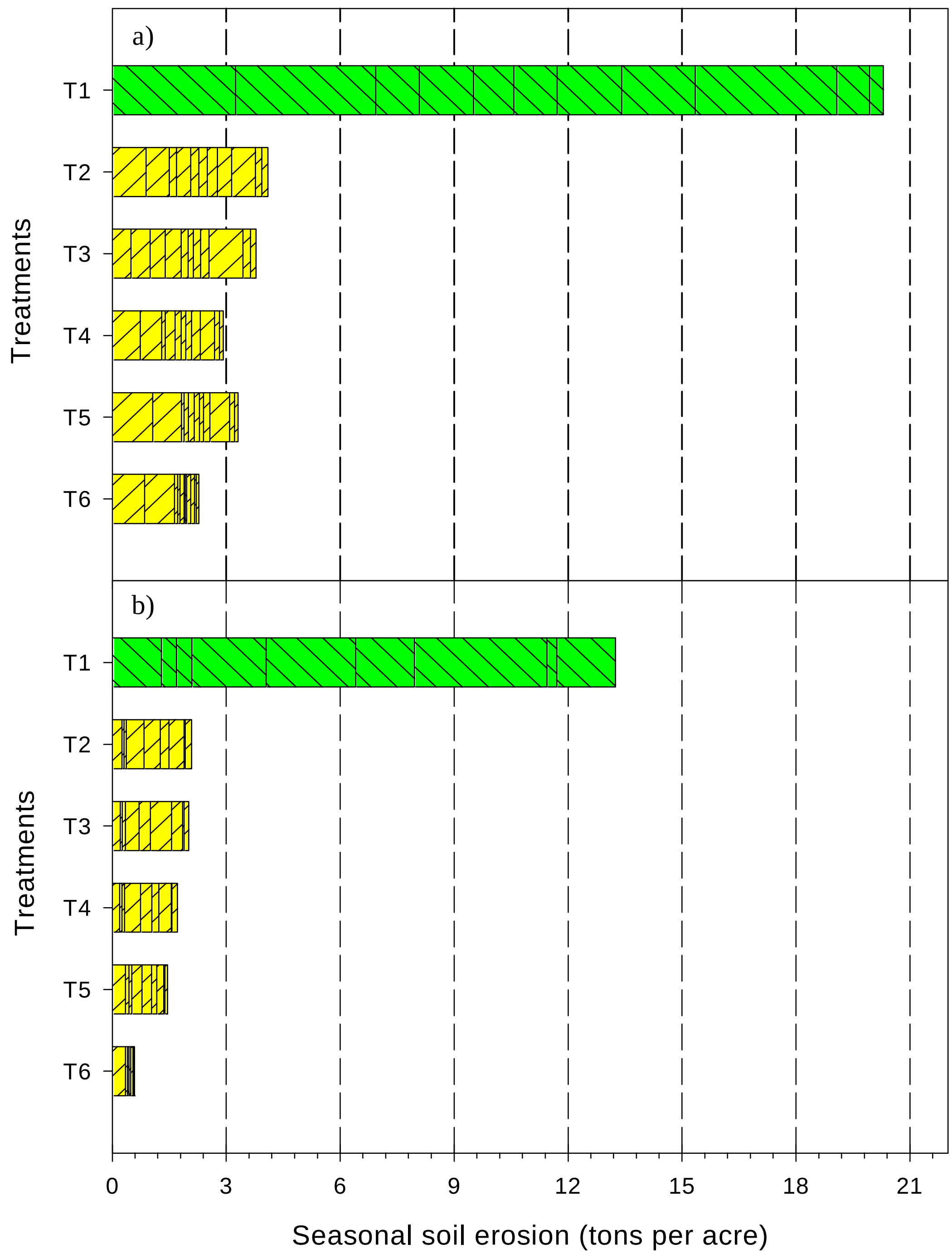
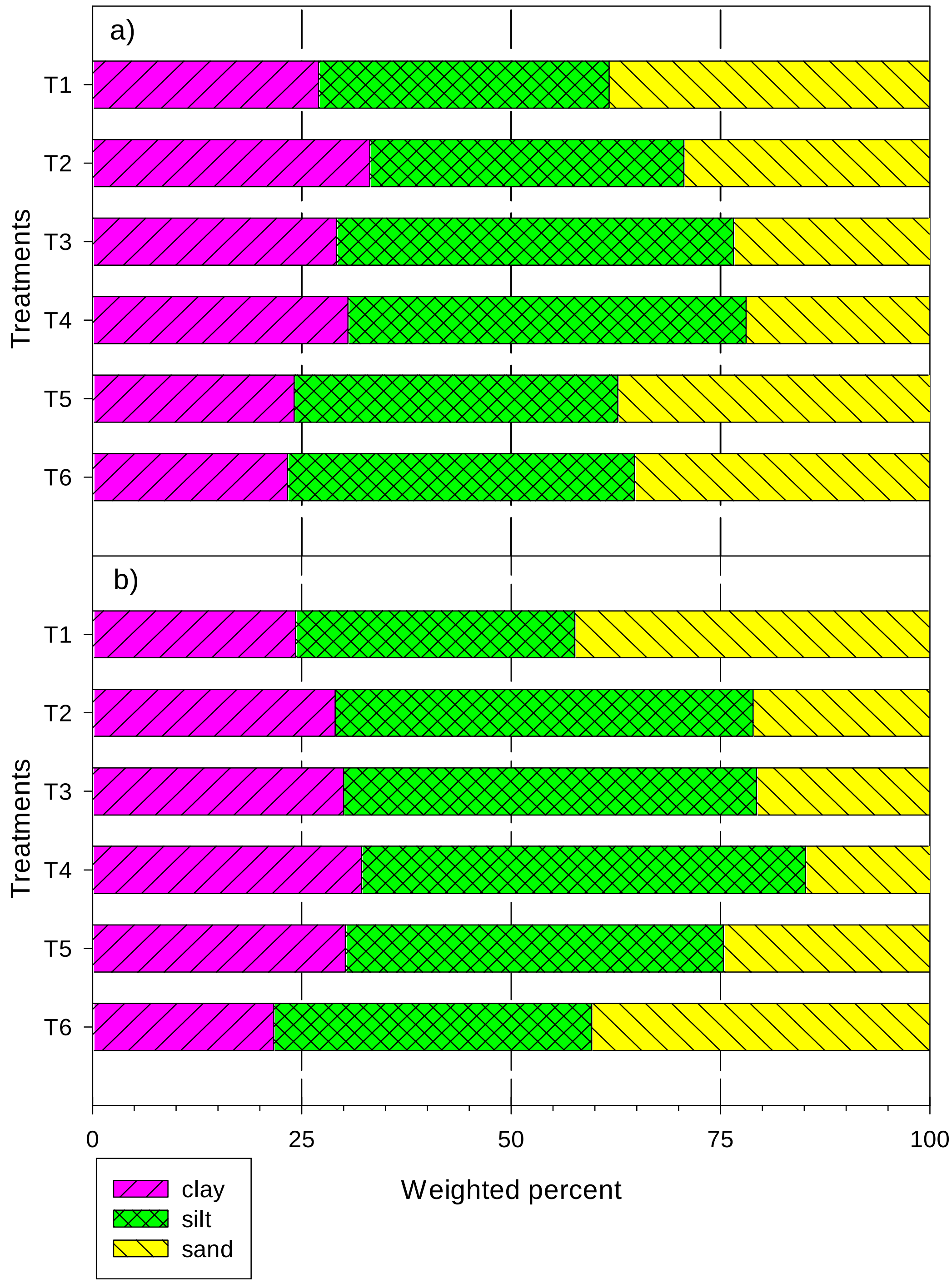
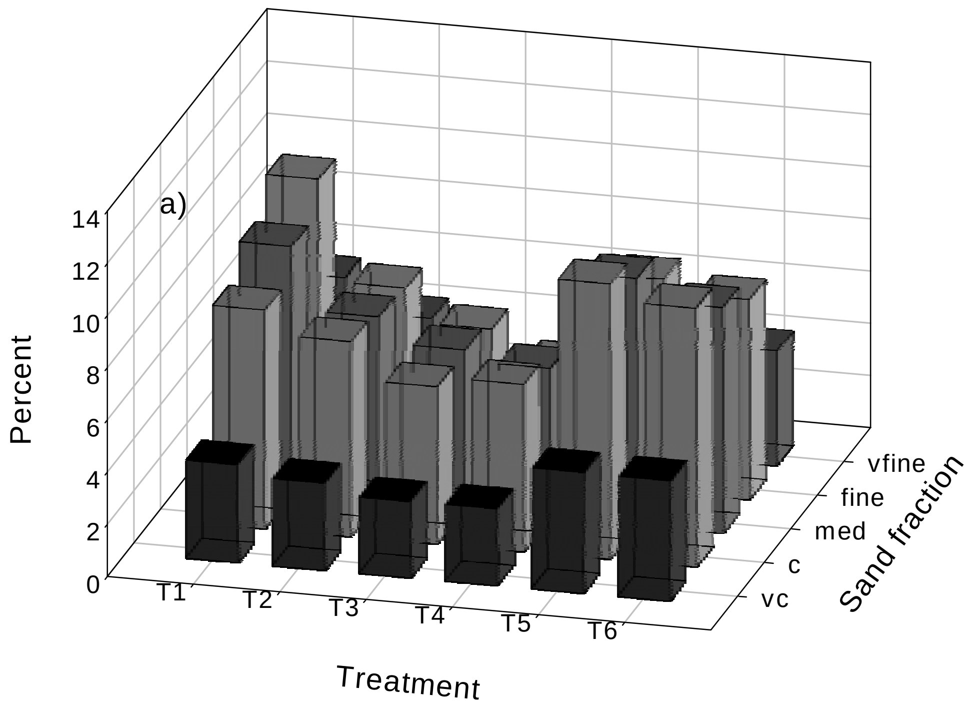

a)
b)
Treatments
T1
T2
T3
T4
T5
T6
0
3
6
9
12
15
18
21
Seasonal soil erosion (tons per acre)

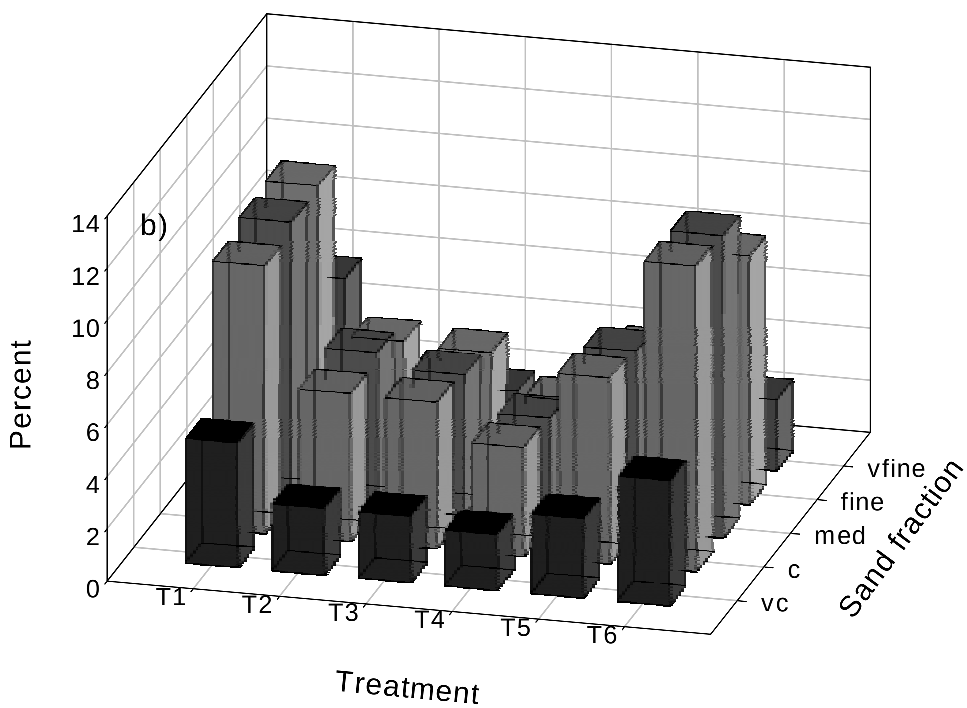
Figure. 4.2a-b. Weighted average clay, silt and sand composition of collected soil erosion in 1996 (a) and 1997 (b) resulting from five conservation tillage flue-cured tobacco production systems and conventional tillage. Treatment designations refer to conventional tillage (T1) and conservation tillage (T2-T6). Row cultivation was applied at early, late and layby (T2), early and layby (T3), late and layby (T4), layby (T5) and none (T6).


a)
b)
Treatments
T1
T2
T3
T4
T5
T6
0
25
50
75
100
Weighted percent
clay
silt
sand

4.3a-b. Weighted average very coarse (vc), coarse (c), medium (med), fine, and very fine (vf) sand composition of collected soil erosion in 1996 (a) and 1997 (b) resulting from five conservation tillage flue-cured tobacco production systems and conventional tillage. Treatment designations refer to conventional tillage (T1) and conservation tillage (T2-T6). Row cultivation was applied at early, late and layby (T2), early and layby (T3), late and layby (T4), layby (T5) and none (T6).

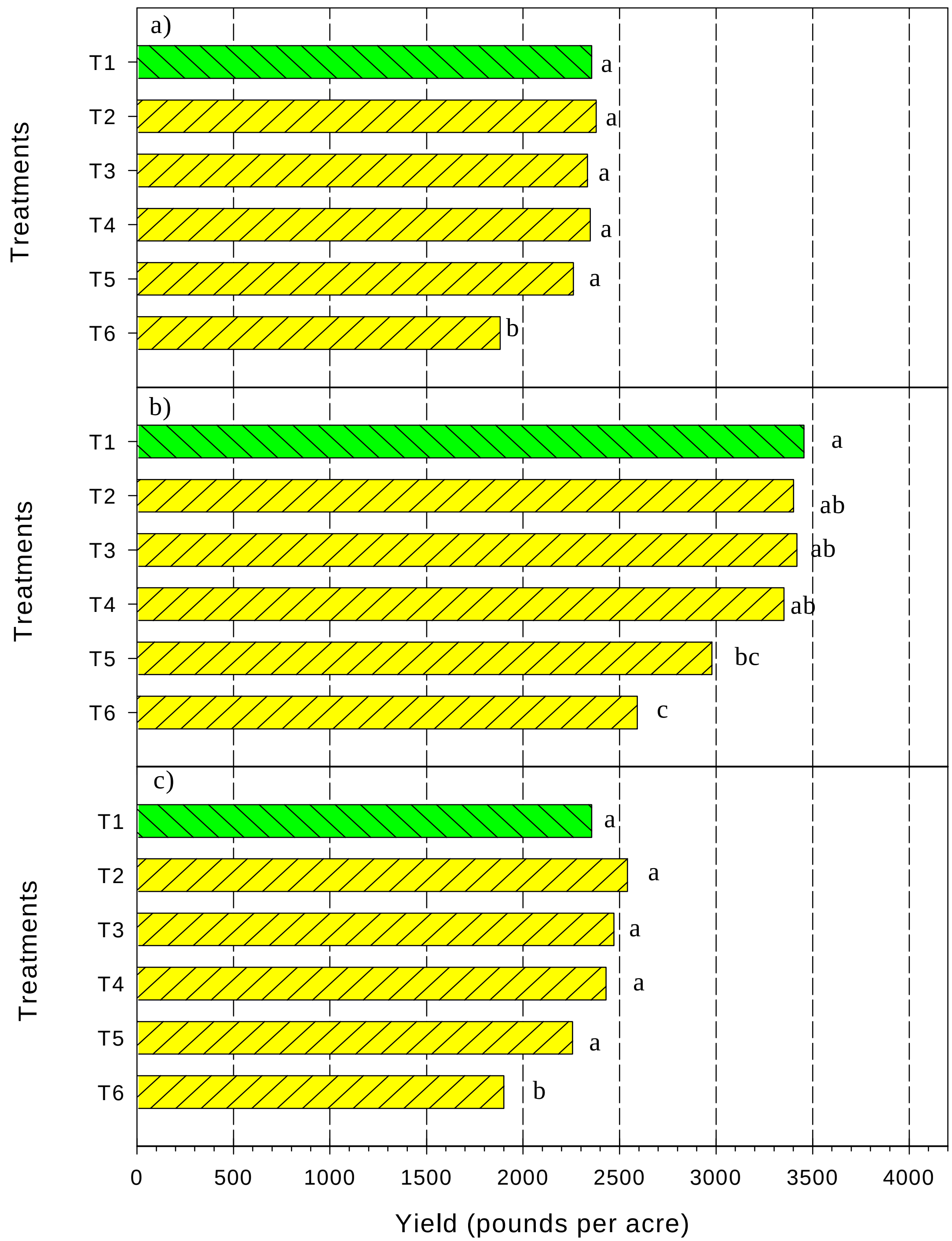


a)
Percent
14
12
10
8
6
4
2
0
T1
T2
T3
T4
T5
T6
Treatment
vfine
fine
med
c
vc
Sand fraction



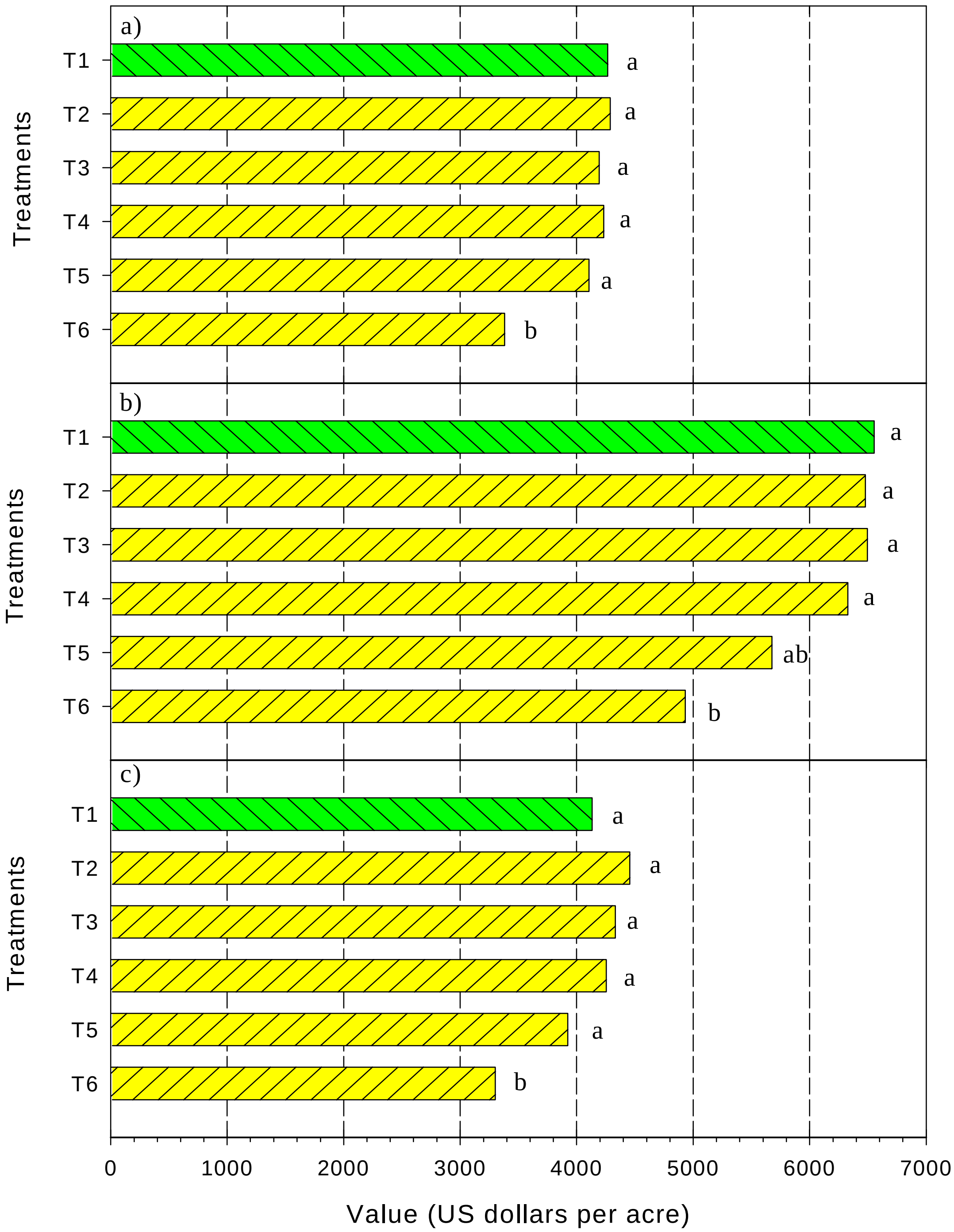
b)
Percent
14
12
10
8
6
4
2
0
T1
T2
T3
T4
T5
T6
Treatment
vfine
fine
med
c
vc
Sand fraction

Figure 4.4a-c. Flue-cured tobacco yield of five conservation tillage production systems and conventional tillage in 1995 (a), 1996 (b) and 1997 (c). Treatment designations refer to conventional tillage (T1) and conservation tillage (T2-T6). Row cultivation was applied at early, late and layby (T2), early and layby (T3), late and layby (T4), layby (T5) and none (T6). Treatment means within a year followed by the same letter are not significantly different, $LSD_{(0.05)}$.



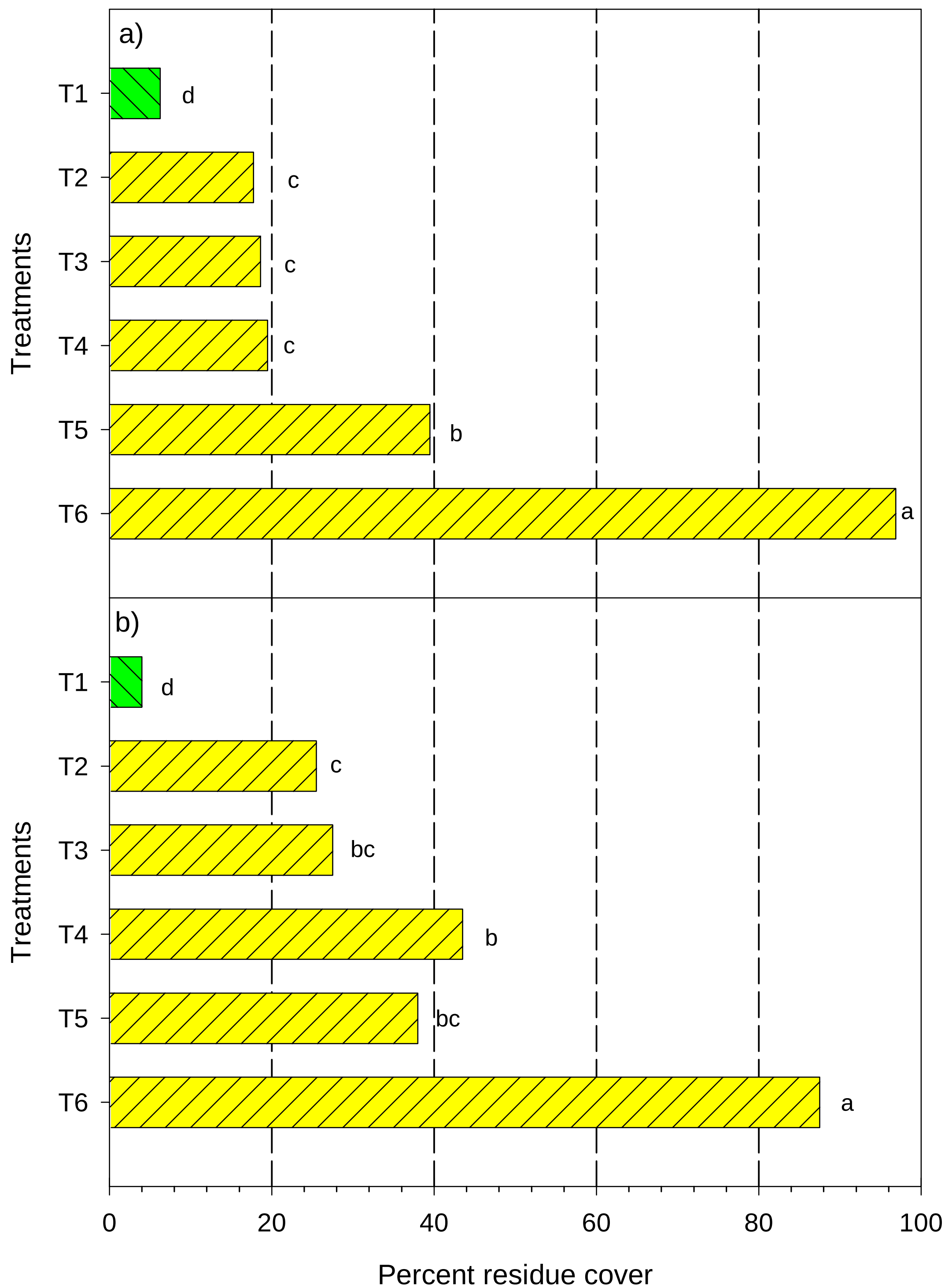
a)
b)
c)
Treatments
Treatments
Treatments
T1
T2
T3
T4
T5
T6
a
a
a
a
a
b
a
ab
ab
ab
bc
c
a
a
a
a
a
b
0
500
1000
1500
2000
2500
3000
3500
4000
Yield (pounds per acre)

Figure 4.5a-c. Flue-cured tobacco value of five conservation tillage production systems and conventional tillage in 1995 (a), 1996 (b) and 1997 (c). Treatment designations refer to conventional tillage (T1) and conservation tillage (T2-T6). Row cultivation was applied at early, late and layby (T2), early and layby (T3), late and layby (T4), layby (T5) and none (T6). Treatment means within a year followed by the same letter are not significantly different, $LSD_{(0.05)}$.



a)
b)
c)
Treatments
T1
T2
T3
T4
T5
T6
a
a
a
a
a
b
a
a
a
a
ab
b
a
a
a
a
a
b
0
1000
2000
3000
4000
5000
6000
7000
Value (US dollars per acre)

Figure 4.6a-b. Cover crop residue of five conservation tillage flue-cured tobacco production systems and a conventional tillage production system remaining on the soil surface following layby cultivation in 1996 (a) and 1997 (b). Treatment designations refer to conventional tillage (T1) and conservation tillage (T2-T6). Row cultivation was applied at early, late and layby (T2), early and layby (T3), late and layby (T4), layby (T5) and none (T6). Treatment means within a year followed by the same letter are not significantly different, $LSD_{(0.05)}$.


a)
b)
T1
T2
T3
T4
T5
T6
d
c
c
c
b
a
d
c
bc
b
bc
a
Treatments
0
20
40
60
80
100
Percent residue cover