Chapter V.

Impact of Crimson Clover and Row Cultivation on the Agronomic Performance of Conservation Tillage Produced Virginia Dark-fired Tobacco

Abstract

Rye, wheat, crimson clover and mixtures of crimson clover with either rye or wheat were examined as cover crops for conservation tillage Virginia dark-fired tobacco production in 1996 and 1997 at the Virginia Tech Southern Piedmont Agricultural Research and Extension Center in Blackstone, Virginia. The removal of crimson clover containing cover crop residues for hay was examined in both years and row cultivation was applied in 1997. Conservation tillage reduced Virginia dark-fired tobacco yield approximately 779 and 488 pounds per acre in 1996 and 1997, respectively. Removal of cover crop residues for hay did not lower tobacco yield compared to leaving residue on the soil surface. Although conservation tillage reduced Virginia dark-fired tobacco yield, two row cultivations increased yield approximately 247 pounds per acre in 1997. The quality of cured tobacco was not affected by conservation tillage. The nitrogen contribution of crimson clover was minimal in both years of the study and did not affect the agronomic performance of tobacco.

Introduction

The production of Virginia dark-fired tobacco relies on traditional production practices that have changed little over the past 100 years. Producers take pride in their crop and consider production an art rather than a science. The production system is centralized in 14 central Virginia counties on approximately 1,600 acres. Unlike flue-cured tobacco farms, the average Virginia dark-fired tobacco farm is small and often diversified with both livestock and row crop components.

The use of conservation tillage for Virginia dark-fired tobacco production offers unique opportunities. Although leguminous cover crops are discouraged for use in a flue-cured tobacco crop rotation, they are recommended for use with Virginia dark-fired tobacco due to the higher tobacco nitrogen requirement (Reed *et al.* 1996). The nitrogen contribution from legume cover crops is difficult to estimate and can create flue-cured tobacco quality issues resulting from curing difficulty (Hawks and Collins, 1983). Legume cover crop mulches for conservation tillage Virginia dark-fired tobacco production offer the opportunity to contribute nitrogen for tobacco growth and a potential side benefit of high quality hay.

Wiepke *et al.* (1988) investigated legume cover crops for conservation tillage flue-cured tobacco production in North Carolina. Tobacco yield and quality resulting from hairy vetch, crimson clover and mixtures with either wheat or rye cover crop mulches was similar to conventional tillage. This success with flue-cured tobacco, although discouraged due to difficulties with nitrogen fertilization, offers promise for the use of legumes in a conservation tillage production system for Virginia dark fired tobacco.

In an effort to evaluate the potential of legume cover crop mulches for conservation tillage Virginia dark-fired tobacco production, a two-year research study was initiated at the Virginia Tech Southern Piedmont Agricultural Research and Extension Center in Blackstone, Virginia. The objectives of this study were to:

1. study the impact of various cover crop mulch treatments on the yield and quality of conservation tillage produced Virginia dark-fired tobacco.
2. study the nitrogen balance of various cover crops for Virginia dark-fired tobacco growth.
3. evaluate the effect of row cultivation on yield and quality of conservation tillage produced Virginia dark-fired tobacco.

Materials & Methods

Field experiments were conducted at the Virginia Tech, Southern Piedmont Agricultural Research and Extension Center near Blackstone, Virginia in 1996 and 1997 on a moderately sloped Mayodan sandy loam soil (Typic Hapludult, fine loamy, siliceous, thermic). Nine cover crop treatments were evaluated for use in a conservation tillage production system for Virginia dark-fired tobacco. Conventional tillage (treatment T1) was compared to eight conservation tillage production systems utilizing the following cover crops:

Treatment	Cover crop mulch
T2	wheat
T3	rye
T4	crimson clover
T5	wheat and crimson clover
T6	rye and crimson clover
T7	crimson clover hay
T8	wheat and crimson clover hay
T9	rye and crimson clover hay

Row cultivation was used in 1997 based on results of a flue-cured tobacco investigation (Chapter IV). Cultivation was applied at early and layby (Appendix D) using rolling cultivators with disk blades. The early cultivation involved a light stirring of the soil to improve aeration and weed control, while the layby cultivation involved an intensive disturbance of the soil surface to form a row ridge around plants before they became too tall for additional cultivation. Cover treatments were replicated four times, arranged in a randomized complete block in 1996, and in a split-plot design in 1997. The split-plot design consisted of cover crop main plots and row cultivation subplots.

Research plots in 1996 were 10.5 feet wide, 40 feet long, and consisted of three crop rows that were each 3.5 feet wide. Plot width was increased in 1997 to 14 feet for accommodation of four tobacco rows. Site preparation began in mid-October prior to each year's study with moldboard plowing, subsoil ripping and disking. Cover crops were broadcast seeded and soil immediately firmed using a cultipacker. The small grain (wheat and rye) seeding rate was 3 bushels per acre alone or 2 bushels per acre when in a mixture with crimson clover. Crimson clover was seeded at a rate of 1/3 bushel per acre either alone or in a mixture. Fertilizer of the analysis 5-10-10 ($N:P_2O_5:K_20$) was applied at a rate of 500 pounds per acre to all plots approximately two weeks after seeding to enhance cover crop growth.

The removal of cover crop residues for hay was performed according to cover crop maturity. The cover crop mixture of rye and crimson clover was harvested approximately one week earlier than the crimson clover, or the wheat and crimson clover mixture. Following hay harvest and yield determination, crude protein, lignin, ADF (acid-detergent fiber) and NDF (neutral detergent fiber) were determined by the Virginia Tech Forage Testing Laboratory. The ADF value represents lignified cellulose and is negatively correlated to digestibility. The NDF value consists of cell walls and is negatively correlated with the voluntary animal intake of the forage.

Following hay harvest, paraquat (Gramoxone Extra™) was applied at a rate of 0.6 lb. a.i. per acre to kill the cover crop growth on all plots. Napropamide (Devrinol™) was subsequently applied at a rate of 1.5 lb. a.i. per acre for additional weed control during 1996. A tankmix of clomozone (Command™) at 1.0 lb. a.i. per acre and sulfentrazone (Spartan™) at 0.3125 lb. a.i. per acre was applied along with the Gramoxone Extra™ prior to transplanting in 1997.

Virginia dark-fired tobacco, variety Brownleaf-JH, was transplanted using a two-row Subsurface Tiller Transplanter™ (B and B No-till, Laurel Fork, VA) equipped with Lannen™ model RT-2 carousel transplanter units (Lannen Plant Systems, 27820 Iso-Vimma Finland). Transplanted plant population was approximately 5000 plants per acre. All rows within a given replication were planted in the same direction to produce similar patterns of residue and soil surface disturbance. Imidacloprid (Admire™) was applied at a rate of 0.09 lb. a.i. per acre for flea beetle and aphid control along with 10 pounds per acre 12-48-8 ($N:P_2O_5:K_20$) Miller (Miller Chemical and Fertilizer Corp., Hanover, PA) Supreme starter fertilizer in the transplant water. A complete tobacco grade fertilizer, 6-12-18 ($N:P_2O_5:K_20$), 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

34-0-0 ($N:P_2O_5:K_20$) at 205 pounds per acre was followed by 140 pounds per acre 15-0-14 ($N:P_2O_5:K_20$) applied using double disk openers at three and four weeks after transplanting, respectively. Remedial insect and sucker control practices were consistent with Virginia Cooperative Extension recommendations (Reed *et al.*, 1996). Cutworms were a major insect problem in both years of study and warranted the use of acephate (Othene™) at a rate of 0.75 lb. a.i. per acre. Due to a rainfall deficit in 1997, irrigation was applied at a rate of ¼ inch per hour using stationary sprinklers on July 9 and on July 17 to maintain proper tobacco growth. Rolling cultivators with disk blades were utilized for row cultivation in 1997.

Soil samples were taken periodically throughout the growing season for a determination of soil nitrate. Soil nitrate was determined by the method of Keeney and Nelson (1982) using an Orion 93-07 NO_3^- electrode.

Treatment effects on plant growth were quantified by a calculation of leaf area. The length and width of the second leaf from the plant apex was measured from two plants per plot in 1996 prior to harvest. Leaf area (Suggs *et al.*, 1964) was calculated using the following formula:

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

Tobacco was stalk harvested and cured with wood fire inside a pole curing structure in both years. Plot weights and official USDA grades were recorded and plot yield, average price, value per acre and grade indices calculated. Grade index, a quantitative description of grade (Bowman *et al.*1988), provides a method of evaluating visual cured leaf quality, average price represents the 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 were analyzed from a core sample of Virginia dark-fired tobacco separated by stalk position (Horwirtz 1980).

Analysis of variance was performed using the PROC GLM procedure in SAS (SAS Institute, 1989) and treatment means separated using the LSD test. The effects of crimson clover and cover crop residue removal on tobacco characteristics and soil nitrate were determined using linear contrasts. A Dunnett's t-test was used to compare conservation tillage soil nitrate, total alkaloid content, and leaf development to conventional tillage.

Results

Yield

Conservation tillage significantly reduced Virginia dark-fired tobacco yield (Figure 5.1) in both 1996 ($\underline{P}$ = 0.0001) and 1997 ($\underline{P}$ = 0.0001). Tobacco yield was reduced an average of 779 and 488 pounds per acre in 1996 and 1997, respectively.

Conventional tillage tobacco yield was significantly higher than any of the cover crop mulches examined in 1996, but was similar to the tobacco yield resulting from the mixture of crimson clover with wheat in 1997. Although no significant differences existed among the various cover treatments in 1996, the crimson clover and rye cover crop for hay exhibited a significantly lower tobacco yield compared to crimson clover for either hay or residue, and the residues of wheat, rye, and the mixture of crimson clover and wheat in 1997.

The removal of cover crop residues significantly increased tobacco yield in 1996 (P = 0.0003) but decreased yield in 1997 (P = 0.6759). Crimson clover significantly increased tobacco yield compared to the small grain cover crops in 1997 (P = 0.0358), but not 1996 (P = 0.8847). Row cultivation (P = 0.0001) increased conservation tillage tobacco yield in 1997 by approximately 247 pounds per acre (Figure 5.2 a). The cultivated conservation tillage yield was similar to conventional tillage.

Grade Index and Price

Grade index (Table 5.1) was significantly reduced by conservation tillage culture in 1996 (P = 0.0129) but not 1997 (P = 0.5791). Conventional tillage exhibited a significantly higher grade index compared to any cover crop mulch in 1996. Cover crop mulch did not affect tobacco grade index. Row cultivation did not increase grade index in 1997 (P = 0.4196). Cover crop residue removal significantly reduced tobacco grade index in 1996 (P = 0.0106) but not 1997 (P = 0.9457). Crimson clover exhibited no effect on tobacco grade index in either 1996 (P = 0.9098) or 1997 (P = 0.1768).

Corresponding to the previous report on grade index, treatment effect on price (Table 5.1) was significant (P = 0.0189) in 1996 but not 1997 (P = 0.4749). Price was significantly reduced by conservation tillage, regardless of cover crop, compared to conventional tillage. A significant decrease in price was observed for both the residue removed and the residue remaining treatments of the crimson clover and wheat mixture. Cover crop residue removal did not affect tobacco price in either 1996 (P = 0.0847) or 1997 (P = 1.0000). Likewise, row cultivation did not significantly increase cured tobacco price in 1997 (P = 0.2336). The use of crimson clover did not affect the price of tobacco in either 1996 (P = 0.9586) or 1997 (P = 0.3274).

Value

Tobacco value (Figure 5.2) was primarily a consequence of the treatment impact on yield, quality and the price received for cured tobacco. Value was significantly reduced by conservation tillage culture in both 1996 (P = 0.0001) and 1997 (P = 0.0001). Value of tobacco was similar for the conservation tillage treatments in 1996, but different in 1997. Conventional tillage tobacco value was similar to that observed for conservation tillage using a mixture of crimson clover and wheat residue mulch. The value of tobacco produced using the crimson clover and rye mixture for hay was similar to the value resulting from the use of the crimson clover and wheat mixture for hay and the crimson clover and rye residue mixture, but was significantly lower than the other cover treatments.

Row cultivation increased the value of tobacco in 1997 (P = 0.0001) approximately $509 (Figure 5.2 b). The removal of cover crop residue significantly reduced tobacco value in 1996 (P = 0.0003), but not in 1997 (P = 0.0553). Crimson clover did not affect tobacco value in either 1996 (P = 0.9382) or 1997 (P = 0.5677).

Soil nitrate

The level of soil nitrate (Figure 5.4) observed in 1996 (a) and 1997 (b) declined during the growing season regardless of cover crop or conventional tillage. A minimal contribution of cover residue to soil nitrate was observed in both years of the study.

Soil nitrate determined in 1996 at 4 days after transplanting (DAT) (P = 0.01371) and 26 DAT (P = 0.0111), along with observations at 8 DAT (P = 0.0118), 57 DAT (P = 0.0001) and 111 DAT (P = 0.0080) in 1997 indicated a minimal nitrogen contribution of crimson clover. Although a significant cover effect was observed in both years, conventional tillage levels were similar to those of conservation tillage.

Rye, a high biomass producing cover crop, consistently exhibited the lowest level of soil nitrate in both years whereas crimson clover produced the highest level. The small grains reduced soil nitrate levels compared to crimson clover.

Linear contrasts to determine the nitrogen contribution of crimson clover revealed a significant benefit at tobacco transplanting in 1996 (P = 0.0598) but not 1997 (P = 0.4858). As the growing season progressed, the benefit was minimal at 26 DAT in 1996 (P = 0.7404), significant at 57 DAT in 1997 (P = 0.0093), and minimal at 111 DAT (P = 0.8171) in 1997. The contribution benefit of crimson clover to soil nitrate was most pronounced prior to the second observation, 57 DAT, in 1997. Soil nitrate levels were reduced 41 and 44 percent for wheat and rye, respectively, compared to 24 and 25 percent for the wheat and rye mixtures with crimson clover, respectively. In contrast, the conventional tillage soil nitrate level was 38 percent lower. The contribution of crimson clover disappeared after 57 DAT as evidenced by additional reductions of 23 and 53 percent for wheat and rye compared to 46 and 43 for the wheat and rye mixtures with crimson clover, respectively. The reduction for wheat and rye was similar to conventional tillage.

The removal of cover crop residue for hay significantly increased the soil nitrate level on the second observation, 26 DAT (P = 0.0435), in 1996. No significant impact of hay removal was observed at tobacco transplanting in either 1996 (P = 0.1207) or 1997 (P = 0.7622). As the 1997 season progressed, no significant hay removal effect was observed at either 57 DAT (P = 0.3174) or at harvest, 111 DAT (P = 0.3931). The removal of cover residue did not change the percent reduction observed for soil nitrate between observation dates compared to leaving residue on the soil surface. At 49 DAT in 1997, a reduction of 35, 42, and 31 percent was observed for the hay treatments of crimson clover, crimson clover with wheat, and crimson clover with rye whereas similar reductions of 34, 24, and 25 percent were observed for the respective plots with residue remaining. Likewise, similar reductions were observed for the period between the second and third sampling of 1997. The residue remaining plots of crimson clover, crimson clover with wheat and crimson clover with rye exhibited reductions ranging from 36, 46, and 43 percent compared to 24, 46, and 46 for the respective hay treatments.

Row cultivation (Figure 5.5 a) increased the level of soil nitrate by 25 percent on the last observation (P = 0.0001) in 1997. However, a time delay in soil nitrate enhancement by cultivation was observed. Cultivation only increased the soil nitrate level by 3.1 percent for the first observation after cultivation (57 DAT) (P = 0.5496).

Total alkaloid content

The total alkaloid content of cured tobacco (Figure 5.6) was significantly affected in both 1996 (P = 0.0001) and 1997 (P = 0.0109) by conservation tillage culture. Conventional tillage alkaloid content was highest in both years and crimson clover residue was second highest. The lowest values in each year were observed from tobacco produced using the small grain residues.

Conventional tillage exhibited a similar alkaloid content to both crimson clover residue and hay in 1996, but was significantly higher than wheat, rye, the wheat and crimson clover mixture for either hay or residue, and the rye and crimson clover mixture used for either residue or hay. Results in 1997 indicate a response of total alkaloids similar to that of soil nitrate. Again, conventional tillage was similar to crimson clover residue and hay treatments, but significantly higher than either wheat or rye. Conversely, conventional tillage was also similar to the residue treatment of the wheat and crimson clover mixture, and both the residue and hay treatments of the rye and crimson clover mixture.

The removal of cover crop residue significantly increased the total alkaloid content of cured tobacco in 1996 ($\underline{P}$ = 0.0269) but not 1997 ($\underline{P}$ = 0.3531). The use of crimson clover significantly increased the total alkaloid content of cured tobacco in 1997 ($\underline{P}$ = 0.0265) but not 1996 ($\underline{P}$ = 0.7744). Row cultivation significantly increased the total alkaloid content of cured tobacco ($\underline{P}$ = 0.0021) in 1997.

Plant maturity

Plant maturity, quantified using the number of days to flower (Table 5.2), was significantly affected in both 1996 ($\underline{P}$ = 0.0001) and 1997 ($\underline{P}$ = 0.0001) by tillage system. The number of days to flower for conventional tillage was significantly reduced compared to conservation tillage. Conversely, flower development was significantly delayed for conventional tillage in 1997 compared to the hay treatment of wheat and crimson clover.

Row cultivation (P = 0.6777), along with the removal of cover crop residue for hay in 1996 (P = 0.3532), and 1997 (P = 0.7563), had little effect on flower development. Linear contrasts revealed crimson clover significantly delayed flower development in 1996 (P = 0.0292) but not 1997 (P = 0.5074).

Leaf development

The examined cover crops for conservation tillage tobacco culture significantly affected the development of dark-fired tobacco leaves in the top portion of the plant. Table 5.3 illustrates the calculated area of the second leaf from the plant apex immediately prior to harvest in 1996. Conventional tillage exhibited a significantly greater leaf area (P = 0.0001) compared to any of the clover containing mulches, but was similar to the small grains. Residue removal for hay did not reduce leaf area (P = 0.3651), but crimson clover significantly reduced leaf area (P = 0.0008).

Plant Lodging and Ground Suckers

Ground sucker occurrence (Table 5.4) was not affected by tillage system in either 1996 (P = 0.5321) or 1997 (P = 0.8436). Crimson clover cover crop mulch did not affect ground suckers in 1996 (P = 0.4760) or 1997 (P = 0.6732). Hay removal, likewise, exerted no impact on ground sucker development in both 1996 (P = 0.2486) and 1997 (P = 0.9085).

Plant lodging (Table 5.4) was significantly affected by tillage system in 1997 (P = 0.0182) but not in 1996 (P = 0.1378). Conventional tillage exhibited the lowest amount of plant lodging in both years and crimson clover used for either residue or hay displayed the highest amount. The removal of cover crop residue reduced the incidence of plant lodging in 1997 ($\underline{P}$ = 0.0338), but not 1996 ($\underline{P}$ = 0.5474). Crimson clover did not affect plant lodging in either 1996 ($\underline{P}$ = 0.5474) or 1997 ($\underline{P}$ = 0.1806).

Row cultivation reduced the amount of both plant lodging ($\underline{P}$ = 0.0001) and the occurrence of ground suckers ($\underline{P}$ = 0.0001) in 1997 (Figure 5.5). Both factors were reduced 2.5-fold by row cultivation.

Hay Yield and Quality

Hay characteristics observed during 1996 (Table 5.5) indicate a significant impact of cover on both hay yield and quality. The yield of the rye and crimson clover mixture was significantly lower ($\underline{P}$ = 0.0001) than the mixture with wheat, but was significantly higher than crimson clover.

Crude protein content of the crimson clover cover crop mixtures was significantly reduced compared to crimson clover alone ($\underline{P}$ = 0.0002). The mixture with rye was significantly lower than the mixture with wheat.

No significant treatment effect was observed for the lignin content of the three cover crop residues. The highest content was observed for the rye mixture while the lowest value was observed from the wheat mixture.

The digestibility characteristics of both ADF ($\underline{P}$ = 0.0011) and NDF ($\underline{P}$ = 0.0001) exhibited significant cover differences. The mixture with rye exhibited significantly higher values for both ADF and NDF compared to either crimson clover or the wheat mixture. The ADF value of the latter two cover treatments was similar, but the crimson clover NDF value was significantly reduced.

Discussion

Conservation tillage offers Virginia dark-fired tobacco producers the opportunity to reduce soil erosion, harvest high quality hay, and produce an acceptable yielding, high quality tobacco crop. The examined cover crop mulches proved effective for Virginia dark-fired tobacco production, but the need for row cultivation to ensure acceptable yield was apparent.

Tobacco yield reductions associated with conservation tillage production resulted from soil crusting and compaction (Shilling *et al.* 1986; Zartman *et al.* 1976), reduced soil moisture (Ebelhar *et al.* 1981), plant lodging, and a possible allelopathic effect of the decaying cover crop residues (Liebl *et al.* 1992). Row cultivation increased tobacco yield by improving soil aeration, breaking the hard soil surface crust and stirring the stale seedbed. In addition, row cultivation increased the level of soil nitrate and reduced weed competition for sunlight, nutrients and moisture. Row cultivation also moved soil toward the base of plants to provide better support and limit the growth and development of ground suckers.

A reduced soil temperature at tobacco transplanting (Zartman *et al.* 1976) under the cover crop mulch could partially explain the yield reduction observed with conservation tillage. A significant increase in the 1996 tobacco yield resulted from the removal of cover crop residue prior to transplanting. This residue removal exposed the soil surface and therefore allowed for quicker soil warming.

Crimson clover increased tobacco yield in both 1996 and 1997. Possible explanations include a cover created soil temperature effect and a nitrogen contribution. Crimson clover exhibits a shorter growth habit compared to either wheat or rye and therefore allows additional sunlight to reach the soil surface and subsequently warm the soil (Wiepke *et al.* 1988). Crimson clover residue also has a higher protein content compared to the small grains and would therefore decompose and release nitrogen quicker (Ranells and Wagger 1996).

This study, similar to early investigations with tobacco, utilized flat planting. Flat planting minimizes the early season impact of both soil crusting and compaction. Runoff water can flow into the transplanter created trench and reach the tobacco root system with little impedance early in the growing season. Although this can be beneficial in dry seasons, during periods of excessive rainfall the tobacco root system can become saturated and plant losses due to drowning occur. This drowning concern was originally discussed by Moschler *et al.* (1971), who indicated the need for an investigation of pre-formed ridged rows. Conversely, pre-formed ridges divert runoff water away from the planter trench and into the row middle, which consequently reduces the amount of water exposed to the area of plant uptake.

A significant reduction in the 1996 grade index was related to leaf damage resulting from the high winds and excessive rainfall of Hurricane Fran. Conventional tillage grade index was higher than conservation tillage indices due to a harvest differential resulting from delayed growth and maturity of the conservation tillage tobacco. The conservation tillage tobacco matured approximately one week later than the conventional tobacco and was not harvested prior to the Hurricane.

The type of cover crop, along with the removal of residue for hay, could have affected soil moisture content. Ebelhar *et al.* (1981) reported the soil moisture-depleting characteristic of high yielding cover crops. Wiepke *et al.* (1988) indicated cover crop enhanced soil moisture differences reduced the growth of conservation tillage flue-cured tobacco in North Carolina.

Soil nitrate describes a dynamic process controlled by plant nutrient uptake, microbial demand, soil temperature and soil water content. The nitrogen contribution of crimson clover was overshadowed in each year by the high quantity of applied fertilizer nitrogen. Crimson clover, by virtue of its leguminous nature, releases biologically fixed nitrogen during residue degradation. Ranells and Wagger (1996) estimated a nitrogen release of approximately 54 pounds per acre for crimson clover and 43 pounds per acre for a crimson clover and rye mixture in North Carolina after 8 weeks of field residue decomposition. This quantity of nitrogen is only a fraction of the required 135 pounds necessary for Virginia dark-fired tobacco (Reed *et al.* 1996). The time of this nitrogen release may not have coincided with the period of high nitrogen demand for tobacco (Tso, 1990). Researchers have indicated cover crop nitrogen is released during the first 8 weeks of decomposition (Wagger, 1989; Ranells and Wagger, 1996; Wiepke *et al.* 1988). Results of this study indicate the release of nitrogen occurred earlier, during the time between tobacco transplanting and 49 days thereafter.

The removal of cover crop residue did not reduce soil nitrate levels in either year. This observation suggests a possible nitrogen contribution from the crimson clover root systems. Shipley *et al.* (1992), along with Ranells and Wagger (1996), indicated cover crop root systems could not be overlooked during nitrogen contribution calculations. The minimal effect of cover crop residue removal on soil nitrate could relate to a reduced interference of residue with double disk opener operation and consequently, an improved application of fertilizer. The removal of cover crop residue also reduced the demand of nitrogen for residue decomposition.

The release of compounds allelopathic to tobacco growth during cover crop residue degradation possibly explains the yield reduction and plant maturity delay that resulted from conservation tillage. An allelopathic interaction would be most pronounced during the early portion of the tobacco-growing season. Wiepke *et al.* (1988) observed a delayed flue-cured tobacco growth in one year of their study resulting from tobacco transplanted into either crimson clover or hairy vetch cover crop mulches. The delayed tobacco maturity in 1996 complements this earlier observation.

The increase in total alkaloid concentration resulting from the crimson clover containing cover crops likely results from an increased availability of nitrogen for tobacco uptake. Although a release of nitrogen from crimson clover containing residue mulches was not apparent from soil nitrate observations, the total alkaloid concentration indicates a nitrogen release. The reduced level of total alkaloids for the small grain and clover mixtures can be related to the use of nitrogen for small grain residue degradation. Row cultivation increased the total alkaloid concentration of tobacco by allowing easier root penetration and enhancing the breakdown of residue.

Acceptable Virginia dark-fired tobacco yield and quality resulted from conservation tillage production. The cover crop mulches performed equally well and were comparable to conventional tillage when row cultivation was utilized. The yield reduction of 247 pounds associated with the lack of row cultivation is prohibitive to the long-term adoption of conservation tillage for Virginia dark-fired tobacco production.

Although the cover crops performed equally well, economics dictate the most appropriate selection. The small grains would provide an adequate amount of soil cover, but would likely bind a portion of applied nitrogen during the early growing season for residue decomposition. Crimson clover would be prohibitively expensive compared to the small grains due to the higher seed cost and a lower cover crop yield potential. A combination mixture of either wheat or rye with crimson clover would offer the yield advantage of the small grain and the higher quality of crimson clover. The use of these mixtures would be highly advisable from a hay harvest standpoint. The wheat and crimson clover mixture would provide a higher quality hay and similar hay yield compared to the mixture of rye with crimson clover.

Future investigations need to examine hairy vetch and mixtures of hairy vetch with small grains as cover crop mulches for conservation tillage Virginia dark-fired tobacco production. The small grains could provide a support scaffold for hairy vetch growth (Wiepke *et al.* 1988) and lead to higher biomass production. If hairy vetch containing cover crops are utilized, producers need to increase management to avoid formation of viable seeds and consequent weed problems in subsequent crops. Improvements for future investigations include tobacco tissue sampling for nitrogen determination throughout the growing season to estimate the cover crop mulch nitrogen contribution.

Conservation tillage offers Virginia dark-fired tobacco producers the opportunity to reap the many benefits of conservation tillage and also enjoy an acceptable yielding, high quality crop. The harvest of high quality hay allows producers the opportunity to better utilize their land resource.

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Table 5.1. Grade index and market price of eight Virginia dark-fired tobacco conservation tillage production systems and conventional tillage in 1996 and 1997.

Treatment no.	cover crop[1]	Grade index 1996	Grade index 1997	Price 1996	Price 1997
		1-100		US $ per pound	
T1	Conventional tillage	64.0 a	37.5	1.72 a	2.00
T2	Wheat	49.8 b	39.8	1.60 bc	2.00
T3	Rye	49.5 b	42.0	1.62 bc	2.00
T4	Crimson clover	44.5 b	32.8	1.61 bc	1.94
T5	Wheat and crimson clover	48.3 b	36.8	1.65 b	1.98
T6	Rye and crimson clover	48.0 b	36.8	1.61 bc	1.96
T7	Crimson clover hay	41.8 b	36.5	1.60 bc	1.98
T8	Wheat and crimson clover hay	44.8 b	36.8	1.58 c	1.97
T9	Rye and crimson clover hay	47.8 b	32.5	1.61 bc	1.92
	P-value	0.0129	0.5791	0.0189	0.4749
	CV	13.5	16.1	2.9	2.8
	LSD $_{(0.05)}$	9.6	ns	0.07	ns

[1] Cover crop mulch examined for conservation tillage tobacco production. Hay indicates the removal of cover crop residues prior to tobacco transplanting.
Means within a column followed by the same letter are not significantly different.

Table 5.2. The number of days to flower of eight Virginia dark-fired tobacco conservation tillage production systems and conventional tillage in 1996 and 1997.

Treatment no.	Treatment cover crop[1]	Days to flower 1996	Days to flower 1997
		number	
T1	Conventional tillage	46.0 e	62.0 b
T2	Wheat	55.0 d	63.8 ab
T3	Rye	57.0 dc	63.8 ab
T4	Crimson clover	63.5 ab	65.5 ab
T5	Wheat and crimson clover	59.0 c	63.8 ab
T6	Rye and crimson clover	59.0 c	65.5 ab
T7	Crimson clover hay	65.0 a	65.5 ab
T8	Wheat and crimson clover hay	60.5 bc	66.5 a
T9	Rye and crimson clover hay	59.0 c	63.8 ab
	P-value	0.0001	0.0001
	CV	4.4	4.0
	$LSD_{(0.05)}$	3.8	3.8

[1] Cover crop mulch examined for conservation tillage tobacco production. Hay indicates the removal of cover crop residues prior to tobacco transplanting.
Means within a column followed by the same letter are not significantly different.

Table 5.3. Surface area of the second leaf from the plant apex prior to harvest of eight Virginia dark-fired tobacco conservation tillage production systems and conventional tillage in 1996.

Treatment		Leaf area
no.	cover crop[1]	square centimeters
T1	Conventional tillage	1836
T2	Wheat	1553
T3	Rye	1550
T4	Crimson clover	1042 *
T5	Wheat and crimson clover	1401 *
T6	Rye and crimson clover	1163 *
T7	Crimson clover hay	992 *
T8	Wheat and crimson clover hay	1006 *
T9	Rye and crimson clover hay	1432 *
	P-value	0.0001
	CV	23.66

[1] Cover crop mulch examined for conservation tillage tobacco production. Hay indicates the removal of cover crop residues prior to tobacco transplanting.

Means followed by an asterisk are significantly smaller than conventional tillage. (Dunnett's t-test)

Table 5.4. Plant lodging and the occurrence of ground suckers of eight Virginia dark-fired tobacco conservation tillage production systems and conventional tillage in 1996 and 1997.

Treatment		Plant lodging		Ground suckers	
no.	cover crop[1]	1996	1997	1996	1997
		percent		no. per 10 plants	
T1	Conventional tillage	0.0	0.0 c	0.3	1.5
T2	Wheat	0.0	3.3 ab	1.0	3.0
T3	Rye	0.25	2.8 abc	0.0	2.0
T4	Crimson clover	0.25	5.5 a	0.0	2.5
T5	Wheat and crimson clover	0.75	5.5 a	0.3	3.3
T6	Rye and crimson clover	0.0	3.3 ab	0.3	2.5
T7	Crimson clover hay	1.75	4.5 ab	0.3	3.8
T8	Wheat and crimson clover hay	0.50	2.5 bc	1.0	2.3
T9	Rye and crimson clover hay	0.0	1.8 bc	0.3	2.0
	P-value	0.1378	0.0182	0.5321	0.8436
	CV	210.7	61.9	191.2	69.5
	$LSD_{(0.05)}$	ns	2.9	ns	ns

[1] Cover crop mulch examined for conservation tillage tobacco production. Hay indicates the removal of cover crop residues prior to tobacco transplanting.
Means within a column followed by the same letter are not significantly different.

Table 5.5. Hay yield and quality determined in 1996.

Treatment		Yield	Crude protein	Lignin	ADF	NDF
no.	cover crop[1]	tons per acre	percent			
T7	Crimson clover hay	0.60 c	16.52 a	8.25	36.08 b	50.60 c
T8	Wheat and crimson clover hay	1.68 a	10.85 b	7.38	34.25 b	57.17 b
T9	Rye and crimson clover hay	1.18 b	7.61 c	9.14	47.05 a	75.42 a
	P-value	0.0001	0.0002	0.0858	0.0011	0.0001
	CV	16.9	8.5	10.7	5.1	2.6
	$LSD_{(0.05)}$	1.72	0.04	1.44	3.45	2.72

[1] Cover crop mulch examined for conservation tillage tobacco production. Hay indicates the removal of cover crop residues prior to tobacco transplanting.

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

Figure 5.1a-b. Yield of eight Virginia dark-fired tobacco conservation tillage production systems and conventional tillage in 1996 (a) and 1997 (b). Cover crop mulches include wheat (w), rye (r), and crimson clover (cc). Hay indicates the removal of cover crop residue prior to tobacco transplanting. Treatment means within a year followed by the same letter are not significantly different, $LSD_{(0.05)}$.

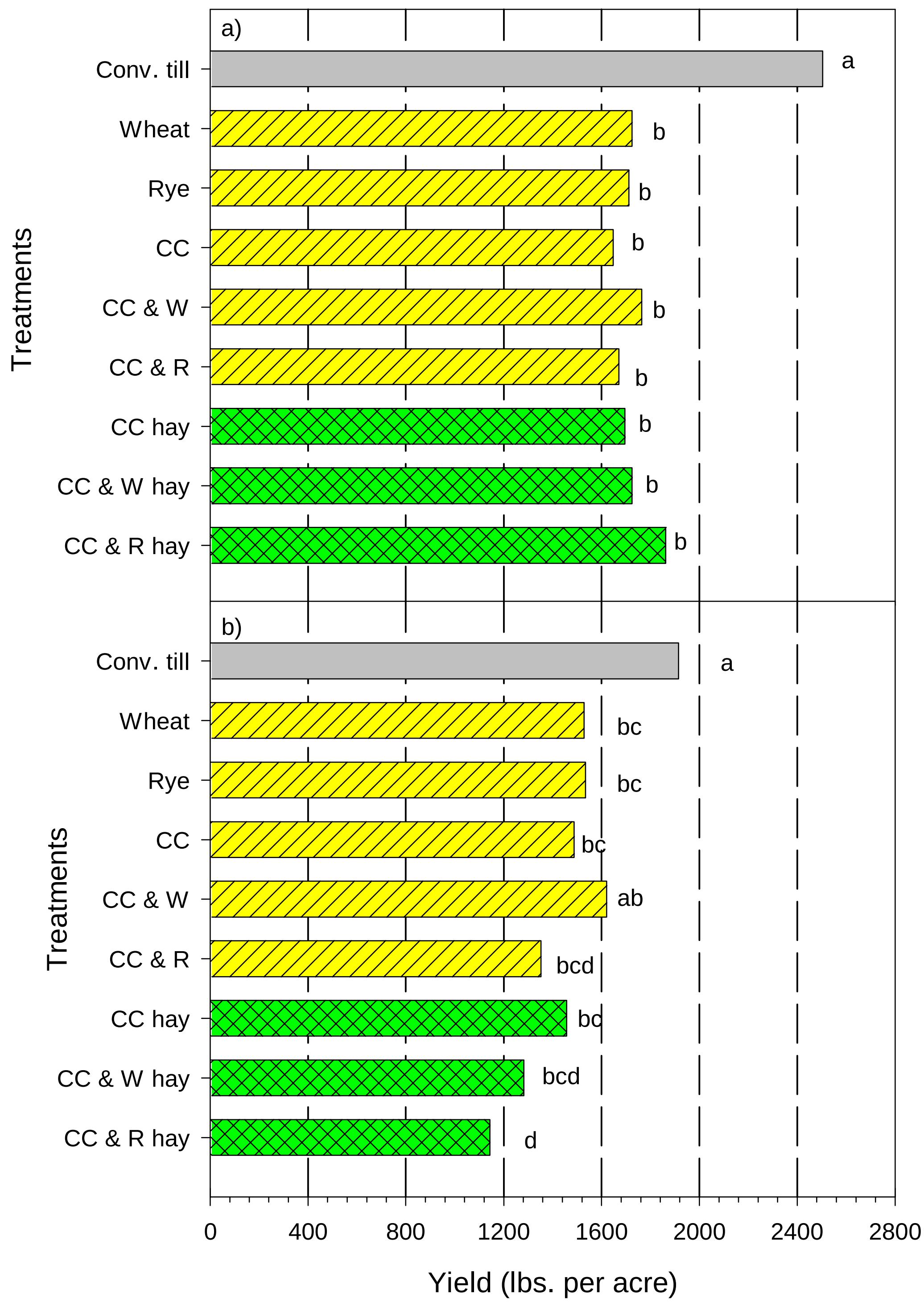

a)
Conv. till
Wheat
Rye
CC
CC & W
CC & R
CC hay
CC & W hay
CC & R hay
a
b
b
b
b
b
b
b
b
b)
Conv. till
Wheat
Rye
CC
CC & W
CC & R
CC hay
CC & W hay
CC & R hay
a
bc
bc
bc
ab
bcd
bc
bcd
d
Treatments
Treatments
0
400
800
1200
1600
2000
2400
2800
Yield (lbs. per acre)

Figure 5.2a-b. Row cultivation effect on conservation tillage produced Virginia dark-fired tobacco yield (a) and value (b). Treatment means followed by the same letter are not significantly different, $LSD_{(0.05)}$.

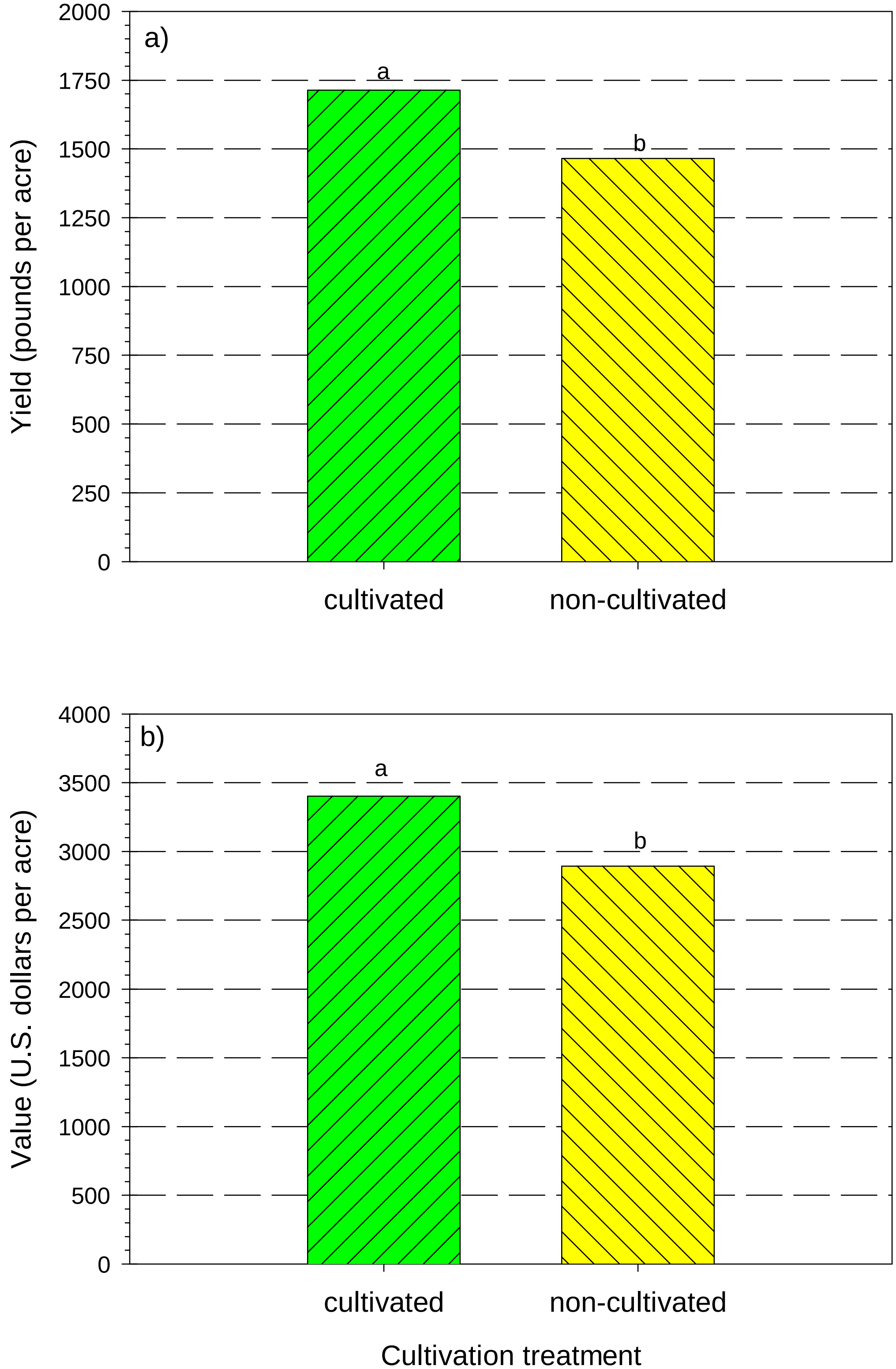

2000
1750
1500
1250
1000
750
500
250
0
a)
a
b
Yield (pounds per acre)
cultivated
non-cultivated
4000
3500
3000
2500
2000
1500
1000
500
0
b)
a
b
Value (U.S. dollars per acre)
cultivated
non-cultivated
Cultivation treatment

Figure 5.3a-b. Tobacco value of eight Virginia dark-fired tobacco conservation tillage production systems and conventional tillage in 1996 (a) and 1997 (b). Cover crop mulches include wheat (w), rye (r), and crimson clover (cc). Hay indicates the removal of cover crop residue prior to tobacco transplanting. Treatment means within a year followed by the same letter are not significantly different, $LSD_{(0.05)}$

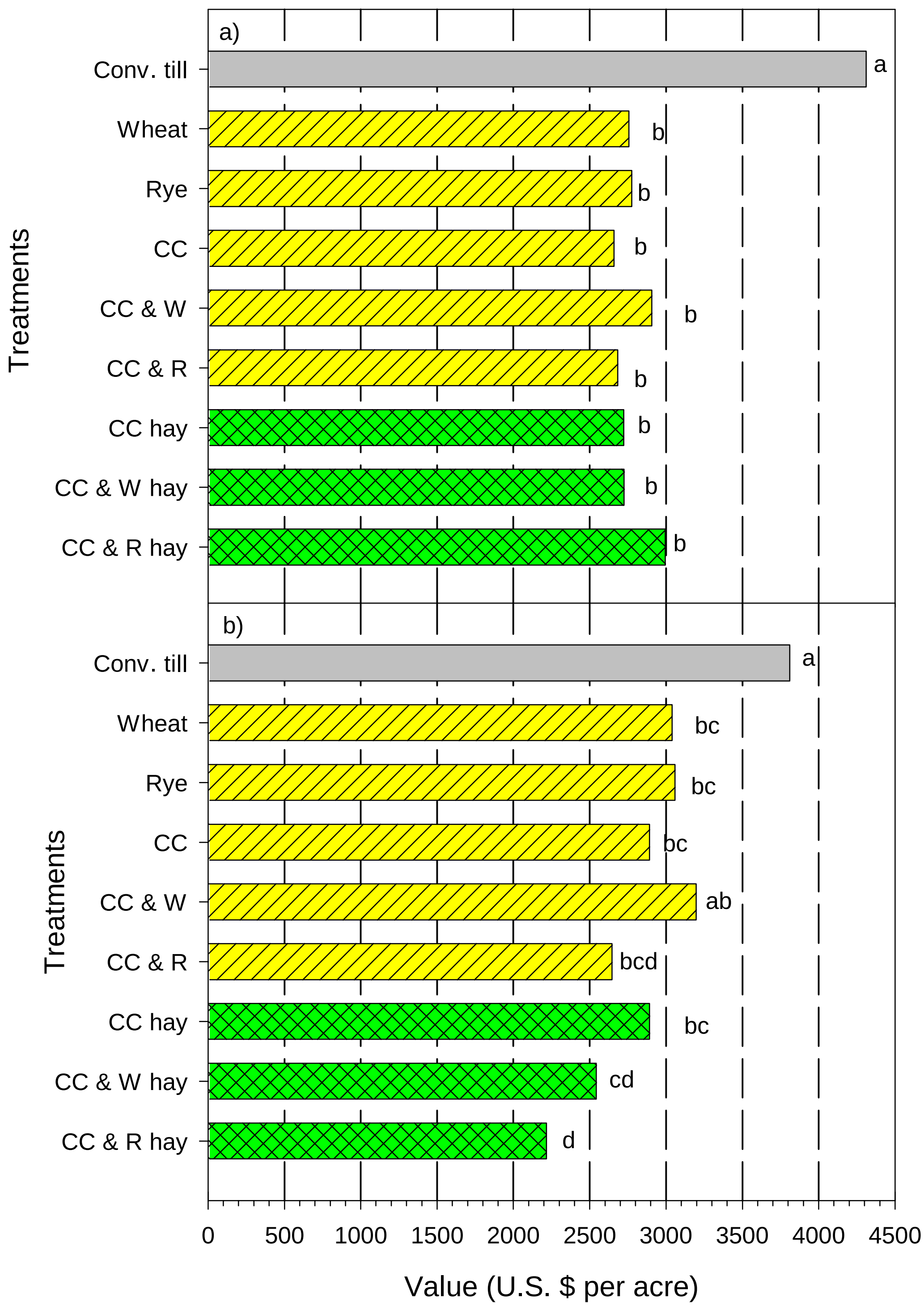
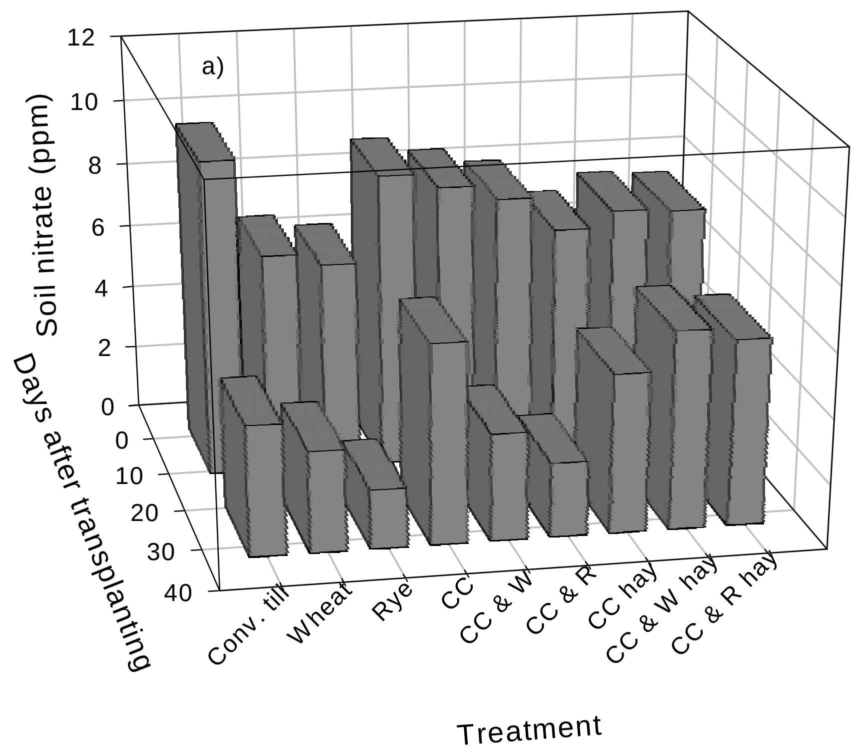

a)
Conv. till
Wheat
Rye
CC
CC & W
CC & R
CC hay
CC & W hay
CC & R hay
a
b
b
b
b
b
b
b
b
Treatments
b)
Conv. till
Wheat
Rye
CC
CC & W
CC & R
CC hay
CC & W hay
CC & R hay
a
bc
bc
bc
ab
bcd
bc
cd
d
Treatments
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Value (U.S. $ per acre)

Figure 5.4a-b. Soil nitrate levels of eight Virginia dark-fired tobacco conservation tillage production systems and conventional tillage in 1996 (a) and 1997 (b).   Cover crop mulches include wheat (w), rye (r), and crimson clover (cc). Hay indicates the removal of cover crop residue prior to tobacco transplanting.


a)
Soil nitrate (ppm)
12
10
8
6
4
2
0
Days after transplanting
0
10
20
30
40
Conv. till
Wheat
Rye
CC
CC & W
CC & R
CC hay
CC & W hay
CC & R hay
Treatment

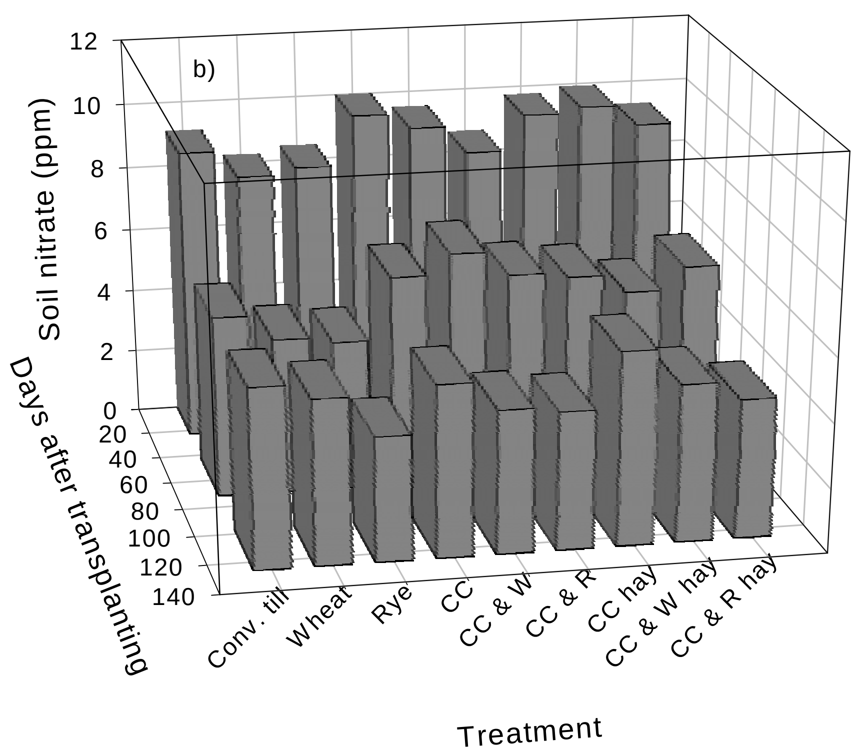
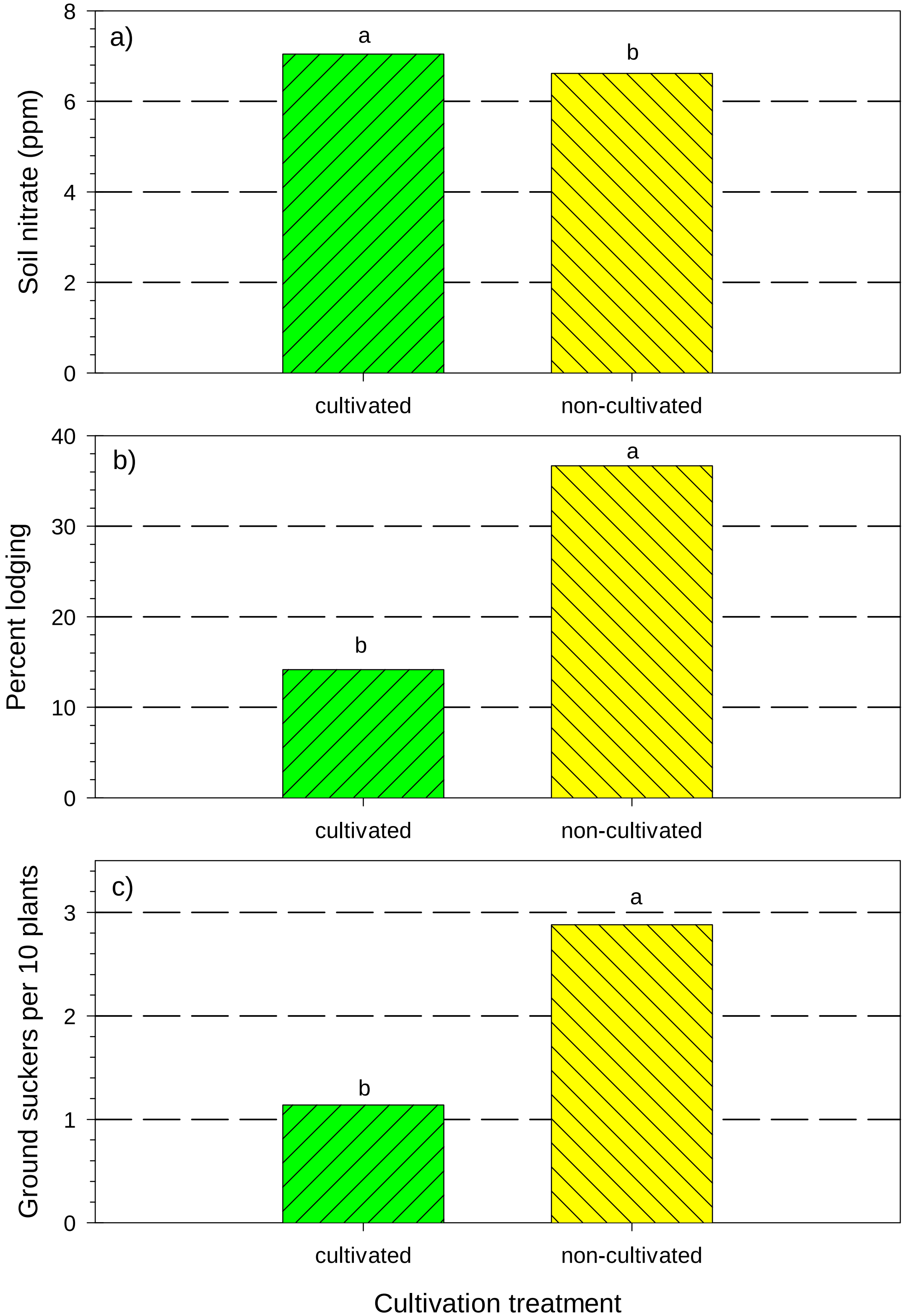
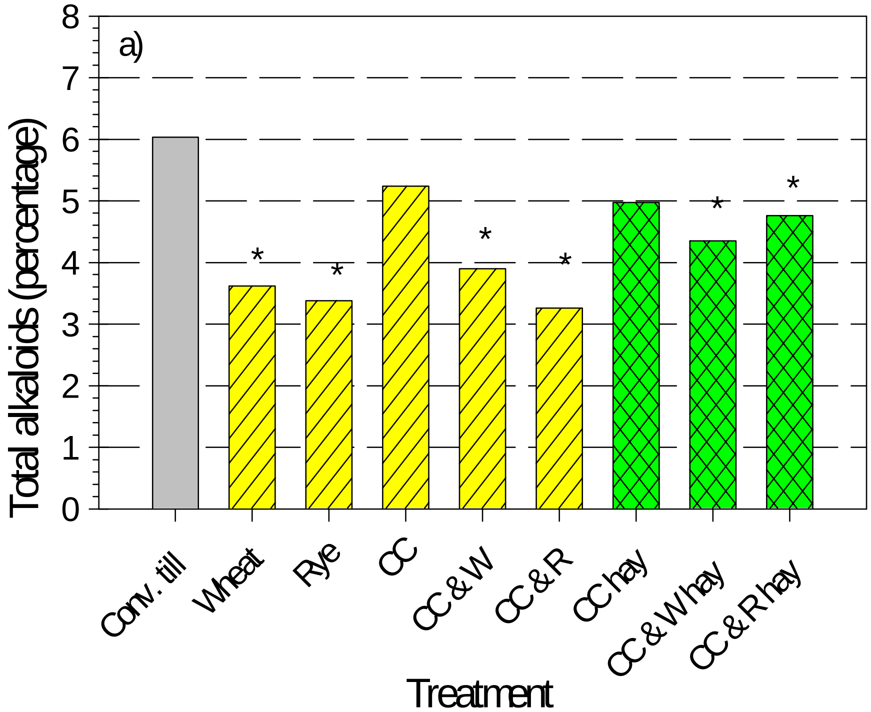

b)
Soil nitrate (ppm)
12
10
8
6
4
2
0
Days after transplanting
20
40
60
80
100
120
140
Conv. till
Wheat
Rye
CC
CC & W
CC & R
CC hay
CC & W hay
CC & R hay
Treatment

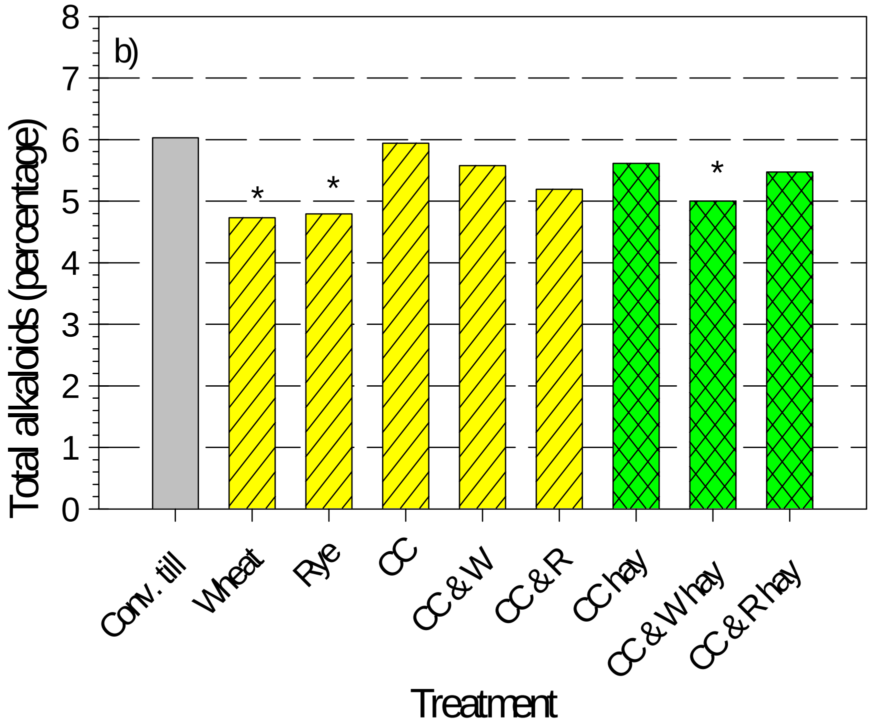
Figure 5.5a-c. Row cultivation effect on soil nitrate (a), plant lodging (b) and ground sucker occurrence (c) in 1997. Treatment means followed by the same letter are not significantly different, $LSD_{(0.05)}$.



a)
Soil nitrate (ppm)
a
b
0
2
4
6
8
cultivated
non-cultivated
b)
Percent lodging
a
b
0
10
20
30
40
cultivated
non-cultivated
c)
Ground suckers per 10 plants
a
b
0
1
2
3
cultivated
non-cultivated
Cultivation treatment

Figure 5.6a-b. Total alkaloid content of eight Virginia dark-fired tobacco conservation tillage production systems and conventional tillage in 1996 (a) and 1997 (b). Cover crop mulches include wheat (w), rye (r), and crimson clover (cc). Hay indicates the removal of cover crop residue prior to tobacco transplanting. Treatment means within a year followed by an asterisk are significantly different from conventional tillage (Dunnett's t-test).


a)
Total alkaloids (percentage)
Treatment
Conv. till
Wheat
Rye
CC
CC & W
CC & R
CC hay
CC & W hay
CC & R hay


b)
Total alkaloids (percentage)
Treatment
Conv. till
Wheat
Rye
CC
CC & W
CC & R
CC hay
CC & W hay
CC & R hay