Influence of cultivar, topping height, and harvest treatment on physical and chemical characteristics of flue-cured tobacco

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(ABSTRACT)

There has been an increased interest among the tobacco industry in the production of tip leaves in flue-cured tobacco. Different harvest treatments of flue-cured tobacco were compared across six cultivars and two topping heights with the objective of identifying tip grade tobacco. Agronomic and cured leaf chemistry data were collected. Cultivar had significant influences on yield, average price, grade index, and value in three growing seasons. NC 71 and RG H51 were the highest yielding cultivars, with grade indices among the highest as well. Increasing topping height increased tobacco yield in two of three years. As topping height increased there was a significant increase in the percentage of tobacco receiving a tip grade. The four harvest treatments focused on the ten uppermost leaves of the plant. Harvest treatments that allowed proper separation of stalk positions (5&5L and 7&3L treatments) resulted in increased yields and tip grades. Harvest treatments that separate upper stalk position tobacco resulted in a higher percentage of tip grades from a tobacco company grader. Chemical analysis identified differences between stalk positions at the top of the plant. In order for cigarette manufacturers to properly blend the tobacco used to make American blend cigarettes, this separation of stalk positions is important. Harvest treatments that combined stalk positions resulted in the loss of these chemical differences. By topping flue-cured tobacco four to five leaves higher than current extension recommendations and separating

stalk positions correctly, tobacco growers can meet the crop throw requirements of tobacco marketing contracts.

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Chapter I

Introduction

The tobacco industry in the United States is much different now than it has been in the past. This is particularly true of the way tobacco is marketed. Previously, the federal tobacco program determined how much tobacco would be marketed in a given year and this was assigned to individual growers as quota. Tobacco growers were allowed to lease or otherwise transfer quota, however total tobacco production remained the same. The amount of quota was largely determined by the forecasted buying intentions of tobacco purchasers, as well as the amount of tobacco held over from previous growing seasons and the purchasers average export sales. Tobacco growers were limited in the amount of tobacco that could be marketed. Price support programs were in place along with the quota program. Minimum prices were guaranteed depending upon USDA grade. Under this system tobacco was marketed through auction sales. A guaranteed market for all but the lowest quality tobacco was provided under this system.

With the tobacco buyout contained in H.R. 4520, The American Jobs Creation Act of 2004, the federal tobacco quota program was eliminated and the price support level removed. The tobacco buyout also eliminated independent grading of tobacco by the USDA AMS tobacco division Tobacco is marketed largely through contracts with tobacco purchasers. Few tobacco growers will plant a crop without a contract in place. Securing and maintaining a contract with a tobacco purchaser is important to tobacco growers. This more direct relationship between the tobacco grower and the tobacco purchaser allows the purchaser more influence over the quality of the tobacco they buy.

Today tobacco growers are more directly concerned with producing tobacco that meets the needs of purchasers than in the past where minimum price support levels existed.

An example of the tobacco purchaser influence on tobacco quality is found in the contract for flue-cured tobacco between Philip Morris USA and their contract growers. In this contract the term “crop throw” is defined as the percentage by weight of the total tobacco delivered and sold that represents each stalk position. One example of a target crop throw is: 15 to 25% lugs and primings, 15 to 22% cutters, 36 to 45% leaf, and 16 to 24% tips. Once the maximum amount of a stalk position allowed in the contract has been delivered, the purchaser reserves the right to refuse additional purchases of tobacco from the same stalk position.

The idea of producing “tips” is relatively new for flue-cured tobacco growers. Under the USDA grading system in use when the quota program was in place, there was no grade designation for tip leaves (Anonymous 2000). The description of tip leaves by Philip Morris USA is leaves that are short in length, narrow in width, compact, heavily bodied, and dark in color (Philip Morris USA 2002).

Under the quota program the price of tobacco was inflated as a result of the lease price paid to non- producing quota owners. In 2005, the first market year without a quota system, there was an approximate 25% decrease in the price paid for tobacco. For tobacco growers who did not lease quota and owned quota for the tobacco they grew, the impact of the price reduction was more significant, because they experienced no decrease in production costs (lease price). Tobacco from other parts of the world (South America and Africa) still costs the tobacco purchasers less than U.S. grown tobacco. However, this price reduction and superior quality is expected to help U.S. grown tobacco compete better on the world market.

In order for flue-cured tobacco producers to maintain their contracts it is important that they be more responsive to purchaser requirements for specific styles of tobacco. The move to contract purchasing of tobacco has made the grower more accountable for the tobacco that they deliver.

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Chapter II

Literature Review

Many studies have been conducted on the influence of leaf population (Campbell et al. 1982a, Elliot 1970a, Elliot 1970b), topping height (Miner 1980a, Campbell et al. 1982a), harvest method (Brown and Terrill 1972, Gooden et al. 1976a, Gooden et al. 1976b), and sucker control (Kittrell et al. 1972, Marshall and Seltman 1964) on yield, quality, and cured leaf chemistry. However, few of these studies have focused on the characteristics of the leaves in the upper stalk positions referred to as “tips”.

Leaf Population and Topping Height

Leaf population is positively correlated with yield. However, as leaf population increases tobacco quality can be reduced to the point that yield advantages are negated (Kittrell et al. 1972). Two ways of increasing leaf population are decreasing plant spacing (within row and between rows) and increasing topping height. Flue-cured tobacco topped to twenty-two leaves produced significantly higher yields and value ($/ha) than tobacco topped to 17 leaves (Collins et al., 1969). This increase in yield was observed when nitrogen fertilization was increased above the recommended rate. Miner (1980a) observed that topping plants at fifteen leaves resulted in significant yield increases over plants topped at twelve leaves. Elliot (1970a) determined that eighteen and sixteen leaf topping heights consistently yielded higher than a topping height of fourteen leaves. That same eighteen-leaf topping height yielded significantly higher than the sixteen-leaf height in two of three years. In a study of close-grown tobacco topped to twelve, sixteen, or twenty leaves, whole-plant, stalk, and lamina yields significantly increased as topping height was increased (Campbell et al. 1982b). Other authors have also observed increased yields as topping height is increased (Arsenault 1986, Brown and Terrill 1972, King 1986, Lamprecht et al. 1979). Certain management protocols can result in yield levels of low-topped tobacco being comparable to the yield of higher topping heights. Gooden et al. (1976a) discovered that by increasing plant population and nitrogen fertility by ten percent, plants topped at fifteen leaves could produce yields equaling the yields of plants topped to eighteen leaves. When plant population and nitrogen rates were equal, the eighteen-leaf topping height produced higher yields. Height of topping directly affects leaf size of tobacco from upper stalk positions. A lower topping height results in higher lamina weight and top leaf area (Elliot, 1970a). Lamprecht et al. (1976a) found similar increases in leaf area as topping height was decreased.

As important as tobacco yield, is tobacco quality. Three categories that contribute to tobacco quality are visible and detectable criteria, physical criteria, and chemical criteria (Tso, 1990). Characteristics of visible and detectable criteria include size, uniformity, finish, foreign matter, damage, color, texture, body, maturity, odor, and flavor. Physical criteria are characterized by filling power, shatter resistance, equilibrium moisture content, strip yield, combustibility, and stalk position. Characteristics of chemical criteria are nicotine, sugar, petroleum ether extracts, mineral components, alkalinity of water soluble ash, total N, protein N, α-amino N, starch, nonvolatile acids, and total volatile bases (Tso 1990). Quality is characterized by USDA quality grades (Anonymous, 2000) and indirectly by price ($/kg) paid for that grade.

Plant topping height effects on tobacco quality are not as consistent as the effects on yield and may vary among stalk positions. Brown and Terrill (1972) observed that for tobacco from bottom stalk positions, a topping height of twelve leaves received a higher price than a topping height of twenty leaves. The opposite is true for tobacco from upper stalk positions. In another study, plants topped at fourteen leaves received higher grade indices than plants topped at eighteen leaves (Elliot 1970a). King (1986) found significant differences for grade index among topping heights in only one of four years, while Miner (1980a) found significantly higher grade indices for tobacco topped to fifteen leaves when compared to tobacco topped to twelve leaves at four of six locations. Ultimately, tobacco desirability is determined by the purchasers of the tobacco. Cigarette manufacturers use differing blends to produce their products and as a result demand tobacco of differing quality grades from different stalk positions. Gooden et al. (1976a) found that company "A" could use only four percent of tobacco topped at twelve leaves while company "H" could use seventy-four percent of the same tobacco. Company "C" could use eighty-four percent of tobacco from plants topped at eighteen leaves while company "F" could use fifty-three percent.

Chemical composition of tobacco contributes to smoke flavor. Two chemical constituents commonly measured are percent total alkaloids and percent reducing sugars. Total nitrogen is used as an indicator of cured leaf nicotine content. Plants topped at eighteen leaves had significantly lower percent nicotine values than plants topped at twelve and fifteen leaves (Campbell et al. 1982a). Similarly, Elliot (1970b) found decreasing percent nicotine values as topping height was increased. Topping height can also affect levels of nitrogen within the tobacco plant. Brown and Terrill (1973) demonstrated that plants topped at twelve leaves had higher total nitrogen levels than plants topped at sixteen or twenty leaves. Gooden et al. (1976b) and Miner (1980b) observed that reducing topping height increases total nitrogen and total alkaloids while levels of reducing sugars were lowered. Arsenault (1986) found that growing season can affect total alkaloid content. As topping height was decreased percent total alkaloids were significantly increased in only one of two years. Total alkaloid content of close-grown tobacco was decreased in lamina, midrib, and whole-plant tissues as topping height increased from twelve to twenty leaves (Campbell et al. 1982b).

Harvest Rate

Flue-cured tobacco is harvested as leaves progressively ripen beginning at the bottom of the stalk. The number of leaf harvests varies depending upon grower management. Historically, flue-cured tobacco was harvested six or more times with a few leaves primed as desired ripeness is obtained. In the past two to three decades, the number of harvests has been reduced with the number of leaves taken with each harvest increased. The most drastic reduction is described as once-over harvesting where all leaves are taken in a single harvest. The result is a reduction in the total amount of harvest labor, but some yield reduction will occur and the desired separation of leaves by stalk position is lost. Leaves from different stalk positions, degree of ripeness being equal, differ in their chemical and physical characteristics and impact the end-use of the tobacco in cigarette blends. As the number of harvests is reduced a compromise must be made with lower stalk position tobacco being over-ripe and upper-stalk tobacco not yet reaching its desired degree of ripeness. Suggs (1986) reported significant yield losses of tobacco harvested when deemed two weeks or more over-ripe. Tobacco deemed to be two weeks under-ripe at harvest resulted in a significant price reduction. Increased emphasis has been focused on the optimal separation of leaves by stalk position to best achieve desired crop throws (separation of leaves with similar end use characteristics). One example is the harvest of the three leaves from the bottom of the stalk, described as "ground primings". A second example is "tip leaves" that are the top three leaves of the stalk. Both ground primings and tips are leaves with highly desirable characteristics that are lost if harvested with leaves of other stalk positions.

Chaplin (1975) found that for two of three cultivars, yield was significantly increased when a conventional multi-pass harvest system was used. Others have reported similar results (Brown and Terrill 1972, Gwynn 1974, Miner 1980a). Brown and Terrill (1972) showed that yield increases that result from multi-pass harvesting are reduced when plant topping height is reduced from twenty to sixteen or twelve leaves. Increasing the number of harvests does not always increase yield. No significant yield difference was observed for tobacco harvested at optimum ripeness (Suggs et al. 1989). Similarly, Gooden et al. (1976a) found no significant yield difference for tobacco topped to eighteen leaves, and harvested in three versus six harvests. Gwynn (1969) found no significant differences among harvest methods ranging from a six-harvest treatment to a treatment that only harvested tobacco two times. However, in a second study conducted by Gwynn (1974) yield was significantly lower for a two-harvest treatment when compared to tobacco harvested three or six times.

Brown and Terrill (1972) observed minimal differences between average prices of normally and once-over harvested tobacco with the only significant difference being between the harvest methods of plants topped to twelve leaves. Price differences between harvest systems have been insignificant for other authors as well (Chaplin 1975, Gwynn 1974, Gooden et al. 1976a, Suggs et al. 1989). Miner (1980a) found that at one location, during one season, once-over harvested tobacco had a lower quality index than did tobacco that was multi-pass harvested. Harvest method effect on tobacco quality can be influenced by other management practices. Tobacco harvested normally had a higher quality index when transplanted on a normal date. Tobacco harvested using the once-over method had a higher quality index when transplanting was delayed (Miner, 1980a).

Harvest rate or harvest method has an inconsistent effect on cured leaf chemistry. Miner (1980b) and Brown and Terrill (1973) showed significantly lower total nitrogen for once-over harvest depending upon location or year. For plants topped to eighteen leaves, no significant difference for total nitrogen content was observed between tobacco harvested in three versus six harvests (Gooden et al. 1976b). Total alkaloid content is affected by harvest method. The low-alkaloid cultivar Coker 139 and a pale-yellow hybrid showed significantly greater percent total alkaloid content under a multi-pass harvest system than when harvested in one harvest (Chaplin 1975). However, there was no significant difference for total alkaloid content of the cultivar NC 95 under different harvest systems. Reducing sugar content was significantly lower in tobacco harvested multiple times compared to tobacco harvested in one or two passes (Chaplin, 1975). Gooden et al. (1976b) showed no difference in total alkaloid or reducing sugar content of tobacco harvested in three versus six harvests. Similarly, there was no significant difference in percent total alkaloids or percent reducing sugars of tobacco harvests in two versus four harvests (Suggs et al. 1989). Miner (1980b) observed significant differences for total alkaloid content at a different location in each of two years. In 1975 at one location multi-pass harvested tobacco had significantly higher total alkaloid content than once-over harvested tobacco, while the following year at a different location the once-over harvested tobacco showed higher total alkaloid content than the multi-pass harvested tobacco. Reducing sugar content was significantly higher for multi-pass harvested tobacco at one location for one year (Miner 1980b). Neas et al. (1978) found that low profile harvested tobacco possessed chemical characteristics similar to normally harvested upper-stalk type tobacco. Tobacco harvested normally (two harvests) produced both lower and upper-stalk tobacco types.

Sucker Control and Time of Topping

Topping of tobacco is the physical removal of the terminal inflorescence along with any axillary buds or "suckers" present at the time. This cultural practice increases tobacco yield and imparts desirable physical and chemical characteristics upon the cured tobacco. The time at which tobacco is topped also affects the yield, quality, and chemical composition of the cured tobacco.

Elliot (1975) discovered that topping during the bud stage resulted in a three-year average yield that was 195 kg/ha higher than topping at the late flower stage. In an earlier study, each of five cultivars produced their highest yields when topped earlier than was the normal cultural practice at the time (Elliot 1966). Marshall and Seltman (1964) showed similar data for both manually and chemically suckered tobacco. Manually suckered tobacco topped in the button or early flower stages showed significantly higher yields than tobacco topped in the full or late flower stages. However, when tobacco was suckered chemically, yield differences were significant among each of these four stages of flower development (Marshall and Seltman 1964). Increased yields as a result of topping tobacco during earlier stages of flower development have been observed by other authors as well (Gupton 1975, Kittrell et al. 1972). A three year yield average of three topping heights showed significant decreases as topping was delayed (Arsenault, 1986). Kelley and Bowman (1990) however found few significant differences for yield among topping stages. At one location an increase in yield was observed as topping was delayed from early button to elongated button and early flower.

The effect of stage of flower development at time of topping on tobacco quality is less predictable than the effect on yield. The grade index of different cultivars is affected by different stages of flower development at topping (Gupton 1975, Kelley and Bowman 1990, Elliot 1966). Marshall and Seltmann (1964) found that mechanically suckered tobacco decreases in price as topping is delayed. Tobacco suckered chemically and topped at the late flower stage was significantly lower in price than tobacco topped at full flower, with tobacco topped earlier at the button and early flower stages falling in-between the two later stages. Kittrell et al. (1972) found that price decreased significantly as topping was delayed.

Similar to grade index, percent total alkaloids, percent reducing sugars, and percent total nitrogen are dependent upon the cultivar in question. Elliot (1966) found that levels of these chemical constituents vary among stage of topping depending on cultivar of flue-cured tobacco. The same is true for cultivars of burley tobacco (Gupton 1975). Marshall and Seltmann (1964) as well as Arsenault (1986) showed significantly higher percent total alkaloids in tobacco topped in the button stage than in tobacco topped at three later stages of flower development. Reducing sugar content was only significantly different for one year; with values decreasing as topping was delayed until the late flower stage (Marshall and Seltmann 1964). Elliot (1975) showed a similar decrease in percent total alkaloids as well as a decrease in percent total nitrogen as topping was delayed. Percent reducing sugars was significantly affected only by a no topping treatment.

Mammoth Cultivars

Tobacco cultivars referred to as “mammoth” are those cultivars that flower under short-day conditions. Conventional flue-cured tobacco cultivars are day-neutral. Flower development in mammoth cultivars can be up to eight to ten weeks later than in conventional flue-cured cultivars (Chaplin 1963). As a result, cultivars that contain the mammoth gene are sometimes referred to as non-flowering because topping takes place before flowers develop. This delay in flower formation until later in the growing season reduces sucker proliferation and increases the number of leaves per plant. Chaplin (1963), Jones and Terrill (1984), and Mann and Chaplin (1957) found that there were decreases in tobacco quality among mammoth cultivars. The mammoth cultivars increased yields sufficient to offset price decreases associated with lower quality. In an effort to increase production of tobacco from upper stalk positions and reduce down-stalk tobacco, Wernsman and Matzinger (1980) grew mammoth cultivars to higher than conventional leaf numbers. Bottom leaves were removed and discarded. When four upper leaves were used to replace four lower ones, an over-compensation of yield occurred. This increase in yield increased percent reducing sugars and caused a decrease in total alkaloid content. King (1986) found that increasing leaf number per plant from 14 to 26 leaves increased yield in the mammoth cultivar NC 22NF. Grade index was increased or unchanged as leaf numbers increased. In agreement with Wernsman and

Matzinger (1980), reducing sugar levels were increased and total alkaloid content was reduced as leaf number was increased.

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Chapter III

The influence of cultivar, topping height, and harvest treatment on the agronomic characteristics of flue-cured tobacco

Abstract

Flue-cured tobacco is harvested as the leaves progressively mature starting with those leaves near the bottom of the plant and ending with the leaves at the top. These different stalk positions differ in agronomic and physical characteristics and are used in different proportions in what are commonly described as American blend cigarettes. The objective of this study was to evaluate the effects of cultivar, topping height, and harvest treatment on the cured leaf from the upper stalk positions. Field studies were conducted in a split-split plot design. Whole plots, subplots, and sub-subplots consisted of cultivars, topping heights, and harvest treatments respectively. Cultivar had significant influences on yield, average price, grade index, and value in three growing seasons. NC 71 and RG H51 were the highest yielding cultivars. These cultivars also received the highest quality grades in 2003 and 2004. Coker 319 consistently produced the lowest yields and quality grades / prices of the cultivars evaluated. Increasing topping height increased tobacco yield in two of three years. Topping height also had a significant effect on production of tip-grade tobacco. Tobacco was evaluated by leaf buyers from Philip Morris USA in 2004 and buying grade group designations were assigned to each plot. As topping height increased there was a substantial increase in the percentage of tobacco receiving a tip (T) grade. Harvest treatments that allowed proper separation of stalk positions (5&5L and 7&3L treatments) resulted in increased yields and T grades. Crop throw requirements for production of tip leaves were more easily met when topping height was increased and stalk positions were correctly separated at harvest.

Introduction

Tobacco quality is as economically important to flue-cured tobacco growers as crop yield. Identification and incorporation of characteristics that contribute to improved tobacco leaf quality is essential for the economic viability of tobacco production in the U.S. The specific quality needs of individual companies differ and addressing the factors that affect these needs has become more important for the U.S. tobacco grower as the tobacco industry moves toward contract purchasing and thus a more direct relationship with the purchaser. Termination of the federal tobacco quota and price support programs means these contracts are the primary mechanism for growers to sell their tobacco. Growers who produce inferior quality tobacco will receive discounts and consistently poor quality may result in termination of contracts.

In recent years, decreasing domestic demand for tobacco products has led to an increased emphasis on international markets. While relatively high in price, superior quality makes U.S. grown flue-cured tobacco competitive on the world market. Foreign grown tobacco is available at substantially lower prices, but often quality is low. U.S. grown flue-cured tobacco has experienced an approximate 25% reduction in price due to the end of the federal tobacco quota and price support programs. This makes U.S. grown tobacco more price competitive on the world market and requires U.S. tobacco growers to find ways to reduce production costs while keeping quality high if production is to remain profitable.

The 2005 growing season contract pricing schedules from three of the major U.S. tobacco purchasers show that a premium will be paid for tip leaves, with the highest prices going to first quality tip grade tobacco. Tip leaves are harvested from the top of the plant but also have specific characteristics that differ from the other stalk positions. In general, tips are short in length, narrow in width, compact, heavily bodied, and are darker in color (Philip Morris USA 2002). Tip leaves possess both physical and chemical characteristics that make them desirable for use in specific American blend cigarettes.

Harvest method and rate can affect both yield and quality (Brown and Terrill 1972, Gwynn 1974, Miner 1980a). Harvest rate is a combination of number of leaves and the frequency with which the leaves are removed from the plant. The once-over harvest method is a procedure where all leaves are "stripped" from the stalk in one pass. This is usually accomplished with specialized mechanical harvesters, so harvest labor is greatly reduced. Such a procedure is a compromise between harvest labor and tobacco leaf quality due to the wide range in ripeness of the leaves. These problems can, through both quality and yield reductions, eliminate savings that result from reduced labor costs. Reducing the number of harvests also creates problems with managing barn space since a greater amount of tobacco is harvested over a shorter period of time. Harvesting tobacco multiple times may result in a reduced need for curing capacity. This would reduce the fixed costs associated with curing (Suggs, 1986).

Tobacco is graded by stalk position and this grade can be influenced by harvest rate. Stalk positions differ in chemical characteristics and are used in different proportions in the production of blended cigarettes. A harvest rate that includes a large number of leaves in each of a fewer harvests will result in stalk positions being combined. Because there is proportionally few tip leaves on each plant, they become lost in the more abundant, larger in size leaf-grade tobacco. Harvest treatments that separate the upper leaves will result in proper identification and grading of tip grade tobacco.

With the adoption of contract purchasing there has been greater emphasis put on the pre-described separation of leaves into stalk positions and this is commonly referred to as “crop throws” (Philip Morris USA 2002).

The height or number of leaves to which flue-cured tobacco is topped may potentially influence the production of tip grade tobacco. Flue-cured tobacco topped to a low height (less than 15 leaves) results in reduced yield as compared to normally topped tobacco (Elliot 1970a, Miner 1980a, Campbell et al. 1982). The current recommendation for flue-cured tobacco is a topping height of 18 to 22 leaves (Reed et al., 2002, Moore 2004). These Extension recommendations are made in an effort to maximize profitability for the producer. The difficulty for tobacco growers is that the grading system for flue-cured tobacco (Anonymous, 2000) does not specify grade standards for tip leaves and thus a clear and consistent definition of “tip leaves” has been elusive. Historical recommendations that maximize yield have been detrimental to the production of tip leaves. When the federal tobacco quota and price support systems were in place, producers had a guaranteed market for their tobacco. Today, in the absence of these programs, the emphasis of Extension recommendations should shift to producing the style of tobacco that will meet specific purchaser requirements. Increasing topping height to near 25 leaves would be expected to increase the amount of tobacco with tip leaf characteristics. However, topping higher may result in increased costs of production due to a greater number of leaves to handle and more trips through the field. The objective of this study was to evaluate the effect of cultivar, topping height, and harvest treatment on the production of tip grade flue-cured tobacco.

Materials and Methods

Field experiments were conducted at the Virginia Polytechnic Institute and State University Southern Piedmont Agricultural Research and Extension Center near Blackstone, Virginia in 2002, 2003, and 2004. The experiments were conducted as a split-split plot design with four replications. Whole plots consisted of six cultivars, which were NC 71, RG H51, Speight G-168, Speight NF-3, Coker 319, and K 326. The six cultivars were selected because of their range in growth characteristics or popularity among growers. All cultivars have been evaluated by and meet the minimum standards of the Flue-cured Tobacco Variety Evaluation Program. Subplots were a high and a low topping height. Plants were topped to 20 and 25 leaves in 2002, 16 and 20 leaves in 2003, and 18 and 22 leaves in 2004. Differences in topping heights between years were necessary due to dramatically different growing conditions.

Sub-subplots consisted of four harvest treatments relative to the upper ten leaves on the plant. The harvest treatments were developed to separate the ten uppermost leaves into distinct groups based on the number of leaves. Due to different topping heights, an additional low-stalk harvest was necessary with the high topping height prior to harvest treatments on the uppermost ten leaves. In the Last-over harvest treatment, the last ten leaves on the plant were harvested as one stalk position. In the Split last-over, the same ten leaves were harvested at one time, but separated into the first seven and the uppermost three leaves (Figure 1). In the Seven and Three Leaves (7&3L) harvest treatment, the last ten leaves on the plant are harvested at different times with the uppermost three harvested at a later time when the leaves were ripe. For the Five and

Five Leaves (5&5L) harvest treatment, the last ten leaves on the plant were harvested at the same time as the 7&3L treatment, but separated into two harvests of five leaves.

Production practices not affected by treatments followed those outlined by Reed et al. (2002). Plots were harvested by hand when a majority of plots were judged to be at the desired level of ripeness. Due to differing maturation times among the cultivars some compromise was necessary and some over-ripening of the early maturing cultivars and harvest of under-ripe tobacco from the late-maturing cultivars did occur.

Cured tobacco was separated and weighed by harvest and USDA official standard grades (Anonymous, 2000) assigned by a USDA AMS tobacco grader. The USDA AMS tobacco grade designations are made up of three components; grade group, quality, and color. Grade group is associated with the position of the tobacco on the stalk. Primings (P) are located at the bottom of the plant. These leaves are the first to mature, are thin in body, and show significant damage. The tobacco from the X group is known as lugs. On the plant, lugs are located above the primings. Lugs have an open structure and show less damage than primings. Tobacco at and just below the middle of the stalk is referred to as cutters and belongs to the C group. Tobacco located at the middle and upper portions of the stalk is referred to as B or leaf grade. Leaf grade tobacco will be heavy in body and show little ground injury. By weight, leaf tobacco typically will be the largest group on the plant. The H group or smoking leaf is located above the cutters on the plant. Smoking leaf tobacco has a more closed structure than those groups from lower stalk positions. Smoking leaf tobacco a sub-classification of the leaf grade and is similar in injury to very ripe leaf grade tobacco. Quality is a numerical scale where 1 shows the least amount of damage and 5 exhibits the highest degree of damage.

While group grade is used to describe stalk position, the color symbol in a USDA grade is used to describe the coloration of that particular tobacco. Color symbols applied to tobacco considered to be "ripe" include Lemon (L), orange (F), orange red (FR), red (R), variegated (K), and variegated red or scorched (KR). Color symbols applied to tobacco considered "unripe" include variegated lemon (KL), variegated orange (KF), variegated dark red (KD), variegated mixed (KM), variegated greenish (KV), and whitish-lemon (LL) (Anonymous, 2000).

Tobacco company buying grades were assigned by tobacco company buyers. Company grades are similar to USDA grades with two exceptions (Philip Morris USA 2002). There are no H or smoking leaf grades included in the company grading system and the company grading system includes tip grades (T). Plot yield (kg ha^{-1}), average price (US\$ kg^{-1}), value (US\$ ha^{-1}), and quality index (Bowman et al. 1988) were calculated.

Leaf measurements were taken from the upper stalk positions prior to harvest in 2002 and 2004. Leaf length was taken from the leaf axil to the tip of the leaf. Leaf width was measured at the widest portion of the leaf. Four plants from each plot were measured with some combination of the 1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th}, 6^{th}, or 10^{th} leaves, from the top of the plant being measured. Leaves measured were determined by harvest treatment (Table 1). Leaf area was calculated as leaf length * leaf width *0.6345 (Suggs et al., 1964).

Analysis of variance was conducted using PROC GLM (SAS Institute, 1987). Treatment means were separated using Fisher's LSD test (Gomez and Gomez, 1984). Data from each year was analyzed separately. Error variances among years were heterogeneous therefore data were not combined across years. These differences were likely due to varying rainfall during each growing season The 2002 growing season was drier than normal while during the 2003 growing season precipitation was much greater than normal (Table 2). Rainfall during the 2004 season was similar to the 50 year average for the area (Table 2).

Results and Discussion

Cultivar – Yield, Grade Index, Average Price, and Value

Yield differences were significant among cultivars in all three years of the study. In 2003 (Table 4), yields of all cultivars were relatively low because of excessive rainfall. In 2002 and 2004, NC 71 (Tables 3 and 5) produced the highest yield and produced the second highest yield among cultivars in 2003 (Table 4). Coker 319 and Speight NF3 were consistently the lowest yielding cultivars. RG H51, Speight G-168, and K 326 produced yields greater than Coker 319 and Speight NF3, and below the yield of NC 71.

Significant differences were observed among cultivars for grade index in all three years. In 2002, NC 71 received the lowest grade index, 52 (Table 3), among cultivars whereas in 2003 and 2004 NC 71 received the highest grade index values, 75 and 80 respectively (Tables 4 and 5). Coker 319 received the lowest quality indices in 2003 and 2004. Coker 319 is an early maturing cultivar and as a result tended to be over-ripe when harvested at the same time as other cultivars.

Table 3 shows that in 2002 Coker 319 at \$3.87 kg^{-1} and Speight G168 at \$3.96 kg^{-1} were the highest average prices received. Conversely, in 2003 (Table 4) the average price of Coker 319 was significantly lower than the average prices of four of the other five cultivars. Coker 319 also had the lowest price in 2004 (Table 5). In contrast to 2002, NC 71 in 2004 received the highest price (\$3.99 kg^{-1}) of all cultivars.

In 2002 Speight NF3 with a value of \$13,627 ha^{-1} was significantly lower in value than other cultivars (Table 3). Tables 4 and 5 show values of \$5397 ha^{-1} and \$10,571 ha^{-1} in 2003 and 2004 respectively for Coker 319 were the lowest among cultivars. With values of \$15,620 ha^{-1} in 2002, \$8554 ha^{-1} in 2003, and \$16,268 ha^{-1} in 2004, NC 71 consistently produced value as high as or higher than other cultivars included in the test.

Cultivar – USDA Group Grades, USDA Color Grades, and Philip Morris Buying Grades, Price, and Value

Group grades that apply to the upper 10 leaves were of the most importance to this study and include the C, B, and H grades. X and P grades are assigned to tobacco from lower stalk positions. There were no significant differences among cultivars for the C or B grades in 2002 and 2003 (Tables 6 and 7). In 2004, Speight NF3 and K 326 received the lowest percentage of C grades (Table 8). RG H51, NC 71, Speight G168, and Coker 319 received similar percentages of C grades. In 2004, Coker 319 and Speight G168 received the lowest percentages of B grades (Table 8). No H grades were assigned to any tobacco in 2002. In 2003, RG H51 received the highest percentage of H grades, which was double the percentage of Speight NF3 (Table 7). In 2004, the percentage of H grades was higher than previous years. These ranged from a low of 9% for K 326 to a high of 25% for Speight G168. In 2003 and 2004, Coker 319 received a small percentage of nondescript (N) grades (Tables 7 and 8). This is the result of delayed harvest of an early maturing cultivar, and subsequent over-ripening of the tobacco.

The majority of cured-leaf from all plots in all years received L, F, or K color grades. An exception was in 2002 when a small percentage of tobacco received L color grades (Table 9) indicating that tobacco may have been thinner bodied compared to other years. In 2002 there was a relatively high (as compared to 2003 and 2004) percentage of KF color grades. Differences among cultivars were significant. Other color grades received in 2002 include those assigned to unripe or immature tobacco (Table 9). Along with L, F, and K color grades, the KM grade was given to tobacco in 2003. There were no significant differences among cultivars for color grade in 2003 (Table 10). In 2004, there were significant differences among cultivars for the K color grade (Table 11). Speight NF3 received the highest percentage of K tobacco, 44% and NC71 received the lowest, 23% (Table 11).

In 2004, tobacco company buyers were invited to Southern Piedmont AREC to evaluate and apply their company buying grades to tobacco from this study. These evaluations were not made in the previous years. Using a price list corresponding to the buying grades, average price and value were calculated for the company buying grades. As with the USDA group grades, the P and X buying grades are assigned to tobacco from the lower stalk positions. Tobacco from the upper ten leaves in this study received C, B, or T grades (Philip Morris USA, 2002).

Among cultivars NC 71 received the highest percentage of C grades (Table 12). Coker 319 and Speight NF3 produced the lowest percentage of C grade tobacco (Table 12). There was no significant influence of cultivar on the percentage of B or T-grade tobacco. Among cultivars percentage of B grades ranged from 24 to 35% (Table 12). Percentage of T grades ranged from 3 for NC 71 to 13% for NF3 (Table 12).

Prices ranged from \$2.98 kg^{-1} for Coker 319 to \$3.11 kg^{-1} for K 326 and RG H51 among cultivars but differences were not significant among cultivars. Value differences were significant among cultivars. Coker 319 resulted in the least value, \$8502 ha^{-1} while NC 71 resulted in the greatest at \$12,440 ha^{-1} (Table 13). These differences in value are the result of significant yield differences among the cultivars.

Cultivar – Leaf Measurements

Among cultivars NC 71 and RG H51 consistently had the largest leaf length, leaf width and leaf area values (Tables 14 and 15). This was the case from leaf ten up to the top leaf on the plant. Leaf area values for Coker 319 were usually just below the leaf area values for NC 71 and RG H51. However, Coker 319 leaves one and two in 2004 had considerably lower leaf area values than the remaining cultivars (Tables 14 and 15). Coker 319 matures early which led to over-ripening and deterioration of these top leaves, and could have been the reason for these low values. K 326 consistently produced leaves with the lowest leaf area values. These low values are a function of leaves being narrower than the leaves of other cultivars. K 326 leaf lengths were often greater than those of Speight G-168, but because the Speight G-168 produced leaves greater in width; leaf area was also greater. Length:width ratios were inconsistent among cultivars, but there was a definite trend for this value to increase in stalk positions near the top of the plant. This trend was most evident in 2004, but also appeared in the 2002 data. For leaf length, leaf width, and leaf area the trend was for values to decline as leaf position moved near the top of the plant. This trend is easily seen in tobacco in the field. Differences in leaf size among cultivars were not great enough to influence the grading of the tobacco by the Philip Morris USA grader. There were no significant differences among cultivars for leaf or tip grades, which are the grades the leaves measured, would commonly receive.

Topping Height – Yield, Grade Index, Average Price, and Value

Influence of topping height on yield was significant in 2002 and 2004. The low topping height had an average yield of 3768 kg ha^{-1} while the high topping height produced 4095 kg ha^{-1} in 2002 (Table 3). This increase in yield as topping height is increased has been observed by others (Collins et al., 1969, Elliot 1970, and Miner 1980). Conversely, in 2004 a low topping height resulted in greater yield. Plants topped to 18 leaves produced 3492 kg ha^{-1} while those topped to 22 leaves resulted in 3401 kg ha^{-1} (Table 5). Plants in the high topping height were topped at a later stage of flower development than the low topping height treatment. This delay in time of topping resulted in reduced yield in the high topping height treatment.

High topping height resulted in higher grade index values in 2002 and 2003 although the difference was significant in 2003 only (Tables 3 and 4). The high topping height treatment received the higher grade index in 2002 and 2003 with the difference in 2003 being significant. Conversely, in 2004 the low topping height had a significantly higher grade index (Table 5). This in consistency has been observed before. Elliot (1970) found that a low topping height received a higher grade index than tobacco topped higher, while other studies have shown higher grade index values for a high topping height (Miner 1980).

Difference in average price was only significant between topping heights in one of three years. The low topping height received a significantly higher price of \$3.94 kg^{-1} while the high topping height received \$3.81 kg^{-1} in 2004 (Table 5). Brown and Terrill

(1972) found that the price of tobacco from different stalk positions was affected differently by topping height.

In 2002, a value of \$15,797 ha^{-1} for the high topping height was significantly greater than a value of \$14,496 ha^{-1} for the low topping height (Table 3). Conversely, in 2004 the low topping height resulted in a value of \$13,788 ha^{-1} while because of the lower yield of the high topping height, value was only \$13,030 ha^{-1} (Table 5). The difference in value between topping heights in 2003 was not significant.

Topping Height – USDA Group Grades, USDA Color Grades, and Philip Morris Buying Grades, Price, and Value

Percentage of C grades for the high topping treatments were significantly higher than the percentages given to the low topping height treatments in 2002 and 2004 (Tables 6 and 7). Conversely, the high topping treatments received significantly higher percentages of B grades in 2002, 2003, and 2004. The additional tobacco from the upper stalk positions of the high topping height resulted in an increased proportion of B grades. The percentage of H-grade tobacco was only significantly different in 2003. The high topping height received a significantly higher percentage of H grades as compared to the low topping height (Table 7). Again, as a result of producing more up-stalk tobacco, these grades were proportionally greater in the high topping height.

Color grades received in 2002 include L, F, K, V, KF, KV, KM, G, and GK (Table 9). Of these color grades, there were significant differences for the F and V grades between topping heights. The high topping height received a significantly higher percentage of both F and V grades. Color grades received in 2003 include L, F, K, V, KL, KF, KM, and G (Table 10). Of these, the high topping height received significantly higher percentages of the L and K grades. The low topping height received significantly higher percentages of the KF and KM grades (Table 10). There were no significant differences between topping heights for color grade in 2004 (Table 11).

Both the low and high topping heights received C, B, and T buying grades from the Philip Morris USA tobacco buyer. The low topping height resulted in a significantly higher percentage of C-grade tobacco, 43% as compared to 26% of the high topping height tobacco receiving the C grade (Table 12). Differences between topping heights for percentage of B grades was not significant (Table 12). As a result of the high topping height tobacco having more upper-stalk tobacco, a significantly higher percentage of T grades was received. The high topping height had 18 % T grades while only 1 % of the low topping height tobacco received a T grade (Table 12).

There were no significant differences between topping heights for price or value based on Philip Morris buying grades and prices (Table 13).

Topping Height – Leaf Measurements

Differences between topping heights for leaf length, leaf width and leaf area were significant in all instances (Tables 14 and 15). Differences for L:W ratio were significant with the exception of the 1st and 2nd leaves in 2002. For leaf length, leaf width, and subsequently leaf area the low topping height resulted in greater values in both years for all leaves (Tables 14 and 15). This is a result of the fact that as leaf position moves toward the top of the plant, leaf size decreases. Even though the leaf numbers (1st, 2nd, 3rd, etc.) were the same, they were in effect shifted to higher positions on the plant for the high topping height. Elliot (1970) and Lamprecht (1976) found similar increases in top leaf size as topping height was decreased. The high topping height generally resulted in higher L:W ratios indicating that leaves were proportionally narrower than leaves from the low topping height, more closely fitting the description of tip leaves from Philip Morris USA. As a result the high topping height did result in significantly greater numbers of tip grades.

Harvest Treatment – Yield, Grade Index, Average Price, and Value

Allowing upper stalk tobacco to remain in the field until ripe, as opposed to harvesting along with the lower stalk positions, increases yield (Chaplin 1975, Brown and Terrill 1972, Gwynn 1974, and Miner 1980). Last-over and split last-over treatments resulted in reduced yield when compared to the 5&5L and 7&3L treatments that more thoroughly separated the upper stalk positions in 2002, 2003, and 2004. The 5&5L and 7&3L treatments did produce higher yields in the 2002 (Table 3) season than the Last-over and Split Last-over harvest treatments however these differences were not significant. Higher yields in the 7&3L and 5&5L harvest treatments are the result of harvests occurring when tobacco is ripe. When tobacco is harvested in one pass low stalk positions can be overripe and deteriorating while higher stalk positions have still not fully developed. Allowing each stalk position to fully ripen without becoming overripe before harvest results in increased yield of the whole crop.

Harvest treatment influence on grade index was inconsistent among years. In 2003, the last-over and split last-over treatments received significantly higher grade index values than the 5&5L and 7&3L treatments (Table 4), while in 2004 the 5&5L and 7&3L treatments received significantly higher grade index values (Table 5). There was no significant influence of harvest treatment on grade index in 2002. Grade indices in both 2003 and 2004 were on average higher than those for the 2002 crop (Table 3).

Significant differences in average price among harvest treatments were only observed for the 2003 growing season. In 2003 the 7&3L and 5&5L harvest treatments resulted in lower average prices than harvest Last-over and Split Last-over harvest treatments (Table 4).

Significant differences among harvest treatments for value were observed in one of three years. The 5&5L and 7&3L harvest treatments resulted in higher values than the last-over and split last-over treatments in 2004 (Table 5). While not significant this trend was evident in 2002 and 2003.

Harvest Treatment – USDA Group Grades, USDA Color Grades, and Philip Morris Buying Grades, Price, and Value

There was no significant effect of harvest treatment on USDA group grade percentages in 2002. The 5&5L and 7&3L harvest treatments produced higher percentages of C grade tobacco than the last-over and split last-over harvest treatments in 2003 and 2004 (Tables 7 and 8). When the stalk positions were separated the characteristics of the C grade weren't lost. In 2004, the last-over treatment received the highest percentage of B grades and the split last-over treatment received the lowest percentage (Table 8). The split last-over treatment received the highest percentages of H grades. When the stalk positions were combined the characteristics of the C grade tobacco were masked while the characteristics of the B and H tobacco were prominent enough that these grades were assigned.

The majority of tobacco in 2002 received F, K, or KF USDA color grades. The last-over harvest treatment received significantly lower percentages of the F grade (Table 9). The last-over, along with the split last-over harvest treatments received significantly higher percentages of the of the K grade (Table 9). There were no significant differences among harvest treatments for the KF grade. Among harvest treatments in 2003 there were significant differences for L, K, KF, KM, and V color grades (Table 10). The last-over treatment resulted in at least 10% fewer L grades than the other harvest treatments (Table 10). The 7&3L and 5&5L treatments that more thoroughly separate the upper stalk positions resulted in significantly fewer K grades, with the 7&3L treatment having significantly fewer than the 5&5L harvest treatment (Table 10). K grades are often assigned when stalk positions are mixed and characteristics of those individual stalk positions aren't prominent enough that other color grades can be assigned. The last-over and split last-over treatments received fewer V grades than did the 7&3L and 5&5L treatments (Table 10). The 7&3L harvest treatment received a significantly higher percentage of both KF and KM color grades than did the remaining harvest treatments (Table 10). There were significant differences for the L, K, and KR color grades among harvest treatments for the 2004 growing season. The 5&5L and 7&3L treatments produced higher percentages of L grade tobacco while the last-over and split last-over treatments produced higher percentages of K grade tobacco (Table 11). The KR grades made up a small percentage of the grades given. The 7&3L and the last-over harvest treatments received the fewest KR grades, 0 and 1% respectively in 2004 (Table 11).

For Philip Morris buying grades there were significant differences among harvest treatments for the occurrence of C and T-grade tobacco but not for the B grade (Table 12). The last-over and 7&3L harvest treatments received the highest percentages of C grades, 35% and 41% respectively. The split last-over treatment received 30% C grades and the 5&5L treatment received 32% C grades (Table 12).

The last-over harvest treatment resulted in the lowest percentage of T-grade tobacco with 7% (Table 12). The smaller leaves at the top of the plant that possess the characteristics of T-grade tobacco were combined with tobacco from lower stalk positions. This amount of upper-stalk tobacco was not great enough to change the grade and as a result received a B grade. The 5&5L treatment produced the highest percentage of T grades with 12%. The additional 2 leaves included in the final harvest of the 5&5L treatment produced a higher (not significantly) percentage of T-grade tobacco than either the split last-over or 7&3L harvest treatments, which separate the uppermost three leaves (Table 12). The weight of these two additional leaves increases the percentage on a weight basis but still possess the correct physical characteristics necessary to receive the T-grade. This shows that for the 7&3L treatment, a similar proportion of tip leaves may have been produced as in the 5&5L treatment, only they were included in the previous harvest with tobacco that was predominantly leaf grade. The last-over harvest treatment received \$3.03 kg^{-1}, significantly lower than 5&5L treatment, using company prices and buying grades (Table 13). The 7&3L and 5&5L harvest treatments had values significantly higher than the last-over and split last-over treatments. The uppermost stalk positions of this tobacco were not only more accurately separated by stalk position, it was also allowed to remain in the field and properly ripen.

Summary

Production of tip-grade tobacco was not significantly influenced by cultivar. However, yield, grade index, and value were higher among the modern cultivars, especially the hybrids. Topping height had the greatest influence on tip production of the variables evaluated. Topping heights above those currently recommended in Extension publications do increase the proportion of tobacco receiving a tip grade. This was also the case for harvest treatments that separate the upper ten leaves into separate stalk positions, and harvest these stalk positions when ripe. Production of these tip leaves does not necessarily increase revenue as differences in price ($ kg^{-1}) and value ($ ha^{-1}) weren't significant in every case. However, in order to meet the crop throw requirements imposed on tobacco growers by tobacco purchasers through marketing agreements, adoption of cultural practices that result in the production of tip leaves will become more important.

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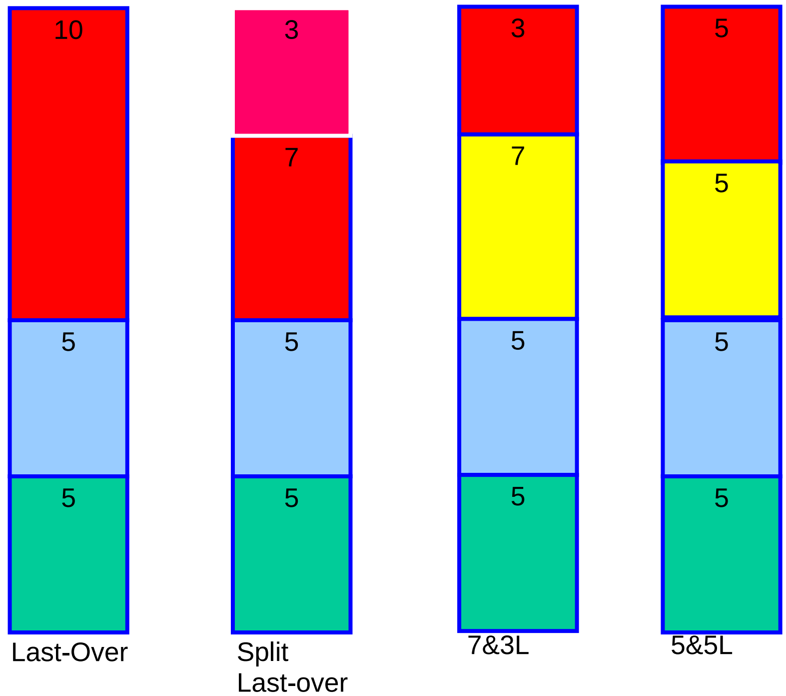

Figure 1. Diagrammatic representation of the four harvest treatments for the low topping height treatment. Numbers indicate the number of leaves removed with each harvest. Alike colors were harvested at the same time. The first three harvests in the high topping height treatment were five-leaf harvests compared to the first two harvests in the lower topping height treatment.

Table 1. Identification of leaves selected for measurement in each harvest treatment

Harvest Regime	Leaf Measured [a]						
	1	2	3	4	5	6	10
Last-over	X				X		X
Split last-over	X	X	X	X		X	X
Seven and three leaves	X	X	X				
Five and five leaves	X		X		X		X

[a] Leaves are numbered from the top of the plant.

Table 2. Rainfall totals for the 2002, 2003, 2004 growing seasons at Southern Piedmont AREC, Blackstone, VA.

Growing Season	**Month**						Season Total
	May	June	July	August	September	October	
2002	3.00	1.68	2.82	3.98	2.08	6.89	20.45
2003	13.73	6.31	6.53	2.54	10.95	2.65	42.71
2004	2.94	7.07	6.83	9.62	5.03	2.21	33.70
50 Year Average	3.74	3.87	4.63	4.06	3.75	3.35	23.40

Table 3. Mean values for yield, average price, grade index, and value of cultivars, topping heights, and harvest treatments from the 2002 field experiment.

	Yield kg ha^{-1}	Average price \$ kg^{-1}	Grade Index[a]	Value[b] \$ ha^{-1}
Cultivar				
Coker 319	3849 c	3.87 abc	65 ab	14,901 a
Speight G-168	3941 bc	3.96 a	69 a	15,611 a
RG H51	4110 ab	3.78 c	56 bc	15,569 a
K 326	3938 b	3.93 ab	65 ab	15,490 a
NC 71	4167 a	3.74 c	52 c	15,620 a
Speight NF3	3565 d	3.81 bc	61 a	13,627 b
CV (%)[d]	11.43	5.68	8.14	16.52
Topping Height				
Low	3768 b	3.84 a	60 a	14,496 b
High	4095 a	3.85 a	63 a	15,797 a
CV (%)	11.43	5.68	8.14	16.52
Harvest Treatment				
Last-over	3874 a	3.86 a	62 a	14,989 a
Split last-over	3868 a	3.86 a	63 a	14,940 a
7&3L	3977 a	3.84 a	61 a	15,290 a
5&5L	4007 a	3.83 a	60 a	15,367 a
CV (%)	11.43	5.68	8.14	16.52

[a] 0-100, higher values indicate tobacco of higher quality (Bowman et al. 1988)
[b] Based on USDA official standard grades for flue-cured tobacco and the average price for that grade for the season.
[c] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.
[d] CV = coefficient of variation.

Table 4. Mean values for yield, average price, grade index, and value of cultivars, topping heights, and harvest treatments from the 2003 field experiment.

	Yield kg ha^{-1}	Average price \$ kg^{-1}	Grade Index[a]	Value[b] \$ ha^{-1}
Cultivar				
Coker 319	1469 c[c]	3.66 b	65c	5397 c
Speight G-168	2172 ab	3.74 ab	69 bc	8173 ab
RG H51	2356 a	3.85 a	74 ab	9102 a
K 326	2126 ab	3.81 a	72 ab	8097 ab
NC 71	2221 a	3.83 a	75 a	8554 a
Speight NF3	1925 b	3.79 a	72 ab	7314 b
CV (%)[d]	13.34	3.23	9.47	14.13
Topping Height				
Low	2026 a	3.77 a	68 b	7655 a
High	2064 a	3.79 a	74 a	7892 a
CV (%)	13.34	3.23	9.47	14.13
Harvest Treatment				
Last-over	1952 b	3.85 a	74 a	7580 a
Split last-over	2018 ab	3.81 ab	72 a	7746 a
7&3L	2096 a	3.70 c	68 b	7790 a
5&5L	2116 a	3.77 b	71 ab	7973 a
CV (%)	13.34	3.23	9.47	14.13

[a] 0-100, higher values indicate tobacco of higher quality (Bowman et al. 1988)

[b] Based on USDA official standard grades for flue-cured tobacco and the average price for that grade for the season.

[c] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.

[d] CV = coefficient of variation.

Table 5. Mean values for yield, average price, grade index, and value of cultivars, topping heights, and harvest treatments from the 2004 field experiment.

	Yield kg ha^{-1}	Average price \$ kg^{-1}	Grade Index[a]	Value[b] \$ ha^{-1}
Cultivar				
Coker 319	2846 e[c]	3.70 d	72 c	10,571 e
Speight G-168	3426 c	3.92 ab	77 b	13,423 c
RG H51	3560 b	3.90 b	79 ab	13,915 bc
K 326	3618 b	3.92 ab	78 ab	14,230 b
NC 71	4064 a	3.99 a	80 a	16,268 a
Speight NF3	3165 d	3.79 c	73 c	12,048 d
CV (%)[d]	5.72	2.22	4.05	6.71
Topping Height				
Low	3492 a	3.94 a	78 a	13,788 a
High	3401 b	3.81 b	75 b	13,030 b
CV (%)	5.72	2.22	4.05	6.71
Harvest Treatment				
Last-over	3363 b	3.88 a	76 bc	13,096 b
Split last-over	3373 b	3.86 a	75 c	13,092 b
7&3L	3513 a	3.89 a	78 a	13,740 a
5&5L	3538 a	3.86 a	77 ab	13,709 a
CV (%)	5.72	2.22	4.05	6.71

[a] 0-100, higher values indicate tobacco of higher quality (Bowman et al. 1988)

[b] Based on USDA official standard grades for flue-cured tobacco and the average price for that grade for the season.

[c] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.

[d] CV = coefficient of variation.

Table 6. Distribution of USDA group grades[a] as a percentage of total crop from the 2002 field experiment.

	P	X	C	B
Cultivar	%[c]			
Coker 319	10 a [b]	16 a	12 a	56 a
Speight G-168	10 a	16 a	11 a	57 a
RG H51	10 a	17 a	11 a	60 a
K 326	9 a	17 a	8 a	66 a
NC 71	9 a	16 a	11 a	62 a
Speight NF3	10 a	18 a	8 a	61 a
Topping Height				
Low	10 a	17 a	3 b	67 a
High	9 b	16 a	17 a	54 b
Harvest Treatment				
Last-over	10 a	16 a	9 a	63 a
Split last-over	10 a	18 a	9 a	58 a
7&3L	10 a	16 a	9 a	61 a
5&5L	9 a	17 a	12 a	61 a

[a] Group grades are an indication of stalk position. P = primings, X = lugs, C = cutters, B = leaf.

[b] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.

[c] Total percentage may not add to 100 due to rounding and minimal nondescript (N) tobacco.

Table 7. Distribution of USDA group grades[a] as a percentage of total crop from the 2003 field experiment.

Cultivar	P	X	C	H	B
	%[c]				
Coker 319	9 a [b]	23 a	22 a	3 b	44 a
Speight G-168	15 a	11 a	17 a	2 b	56 a
RG H51	5 a	16 a	20 a	16 a	43 a
K 326	7 a	16 a	18 a	7 b	52 a
NC 71	11 a	12 a	19 a	7 b	51 a
Speight NF3	7 a	15 a	20 a	8 ab	51 a
Topping Height					
Low	10 a	11 b	19 a	2 b	57 a
High	8 a	19 a	19 a	13 a	41 b
Harvest Treatment					
Last-over	7 a	18 a	11 b	11 a	53 a
Split last-over	10 a	16 a	11 b	13 a	51 a
7&3L	9 a	14 a	28 a	3 b	47 a
5&5L	10 a	14 a	26 a	2 b	47 a

[a] Group grades are an indication of stalk position.
P = primings, X = lugs, C = cutters, B = leaf, H = smoking leaf

[b] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.

[c] Total percentage may not add to 100 due to rounding and minimal nondescript (N) tobacco.

Table 8. Distribution of USDA group grades[a] as a percentage of total crop from the 2004 field experiment.

	P	X	C	H	B
Cultivar			%[c]		
Coker 319	15 a[b]	13 a	25 ab	15 bc	32 c
Speight G-168	7 bc	10 a	26 ab	25 a	32 c
RG H51	9 bc	8 a	29 a	10 bc	44 ab
K 326	11 ab	6 a	22 bc	9 c	51 a
NC 71	7 c	7 a	27 ab	18 ab	42 ab
Speight NF3	14 a	12 a	17 c	18 ab	39 bc
Topping Height					
Low	10 a	7 b	20 b	15 a	48 a
High	11 a	11 a	28 a	17 a	33 b
Harvest Treatment					
Last-over	10 a	11 a	21 b	13	45 a
Split last-over	11 a	10 a	21 b	24 a	34 b
7&3L	10 a	9 ab	24 b	17 b	40 ab
5&5L	11 a	7 b	31 a	11 b	41 ab

[a] Group grades are an indication of stalk position.
P = primings, X = lugs, C = cutters, B = leaf, H = smoking leaf

[b] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.

[c] Total percentage may not add to 100 due to rounding and minimal nondescript (N) tobacco.

Table 9. Distribution of USDA color grades[a] as a percentage of total crop from the 2002 field experiment.

Cultivar	L	F	K	V	KF	KV	KM	G	GK
					%				
Coker 319	1 a[b]	39 a	32 a	2 b	12 b	1 a	11 a	0 a	2 a
Speight G-168	1 a	42 a	40 a	2 b	9 b	0 a	6 a	0 a	0 a
RG H51	1 a	21 b	28 a	9 a	33 ab	1 a	7 a	1 a	0 a
K 326	1 a	32 ab	38 a	5 ab	13 b	0 a	10 a	0 a	1 a
NC 71	2 a	23 b	20 a	1 b	49 a	3 a	3 a	0 a	0 a
Speight NF3	1 a	28 b	43 a	3 b	18 b	3 a	4 a	0 a	0 a
Topping Height									
Low	0 a	27 b	37 a	2 b	26 a	2 a	4 a	3 a	1 a
High	2 a	34 a	30 a	5 a	20 a	1 a	8 a	0 a	0 a
Harvest Treatment									
Last-over	1 a	25 b	42 a	2 a	24 a	1 a	4 a	0 a	0 a
Split last-over	1 a	31 a	39 a	4 a	20 a	1 a	4 a	0 a	0 a
7&3L	1 a	33 a	27 b	4 a	23 a	2 a	9 a	0 a	1 a
5&5L	1 a	32 a	26 b	5 a	25 a	1 a	9 a	1 a	1 a

[a] Component of USDA standard grades. Color grade is based on relative hues, saturation, and color values characteristic of the particular type of tobacco. L = lemon, F = orange, K = variegated, V = greenish, KF = variegated orange, KV = variegated greenish, KM = variegated (scorched) mixed, G = green, GK = green variegated.

[b] Values with the same letter are not significantly different based on Fishers protected LSD at *P* = 0.05.

Table 10. Distribution of USDA color grades[a] as a percentage of total crop from the 2003 field experiment.

	L	F	K	V	KL	KF	KM	G
Cultivar	%							
Coker 319	32 a[b]	2 a	19 a	8 a	7 a	2 a	17 a	0 a
Speight G-168	29 a	13 a	29 a	7 a	3 a	4 a	10 a	2 a
RG H51	34 a	18 a	25 a	8 a	0 a	1 a	12 a	0 a
K 326	40 a	13 a	23 a	5 a	2 a	4 a	12 a	0 a
NC 71	42 a	20 a	20 a	2 a	0 a	4 a	5 a	0 a
Speight NF3	33 a	16 a	33 a	7 a	3 a	2 a	3 a	2 a
Topping Height								
Low	29 b	15 a	18 b	8 a	4 a	5 a	16 a	1 a
High	41 a	13 a	32 a	4 a	1 a	1 b	4 b	0 a
Harvest Treatment								
Last-over	26 b	17 a	34 a	4 b	3 a	0 b	5 b	1 a
Split last-over	37 a	9 a	34 a	2 b	2 a	2 b	7 b	0 a
7&3L	36 a	18 a	11 c	8 a	3 a	6 a	17 a	2 a
5&5L	41 a	12 a	22 b	10 a	3 a	3 b	9 b	0 a

[a] Component of USDA standard grades. Color grade is based on relative hues, saturation, and color values characteristic of the particular type of tobacco. L = lemon, F = orange, K = variegated, V = greenish, KL = variegated lemon, KF = variegated orange, KM = variegated (scorched) mixed, G = green.

[b] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.

Table 11. Distribution of USDA color grades[a] as a percentage of total crop from the 2004 field experiment.

	L	F	K	KR	KL	KF	KM
Cultivar	%						
Coker 319	19 a[b]	43 a	33 abc	3 a	0 a	1 a	1 a
Speight G-168	22 a	36 a	36 ab	1 a	1 a	1 a	3 a
RG H51	24 a	49 a	24 c	1 a	0 a	0 a	2 a
K 326	25 a	42 a	28 bc	2 a	0 a	0 a	2 a
NC 71	16 a	59 a	23 c	0 a	0 a	2 a	0 a
Speight NF3	16 a	36 a	44 a	2 a	0 a	1 a	1 a
Topping Height							
Low	22 a	46 a	28 a	1a	0 a	1 a	2 a
High	19 a	42 a	35 a	2 a	0 a	0 a	1 a
Harvest Treatment							
Last-over	17 b	40 a	40 a	1 b	0 a	1 a	2 a
Split last-over	19 b	41 a	36 a	2 ab	0 a	1 a	2 a
7&3L	25 a	50 a	24 b	0 b	0 a	0 a	1 a
5&5L	21 ab	46 a	27 b	3 a	0 a	1 a	2 a

[a] Component of USDA standard grades. Color grade is based on relative hues, saturation, and color values characteristic of the particular type of tobacco. L = lemon, F = orange, K = variegated, KR = variegated red or scorched, KL = variegated lemon, KF = variegated orange, KM = variegated (scorched) mixed.

[b] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.

Table 12. Distribution of Philip Morris buying grade group designations[a] as a percentage of total crop from the 2004 field experiment.

	P	X	C	B	T
Cultivar	%				
Coker 319	14 ab[b]	20 a	27 c	29 a	10 a
Speight G-168	11 bc	15 a	38 ab	24 a	10 a
RG H51	11 c	11 a	37 ab	29 a	12 a
K 326	11 c	13 a	33 bc	35 a	8 a
NC 71	10 c	13 a	43 a	30 a	3 a
Speight NF3	15 a	15 a	28 c	28 a	13 a
Topping Height					
Low	11 a	14 a	43 a	30 a	1 b
High	13 a	15 a	26 b	28 a	18 a
Harvest Treatment					
Last-over	13 a	14 a	35 ab	31 a	7 b
Split last-over	13 a	15 a	30 b	32 a	10 ab
7&3L	11 a	13 a	41 a	25 a	9 ab
5&5L	11 a	15 a	32 b	29 a	12 a

[a] Philip Morris group designations signify stalk position. P = primings, X = lugs, C = cutters, B = leaf, T= tips.

[b] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.

Table 13. Average price and value based on PM buying grade group designations[a] from the 2004 field experiment.

	Average price[b] $ kg^{-1}	Value $ ha^{-1}
Cultivar		
Coker 319	2.98 a	8,502 e
Speight G-168	3.02 a	10,351 c
RG H51	3.11 a	11,069 b
K 326	3.11 a	11,277 b
NC 71	3.06 a	12,440 a
Speight NF3	3.02 a	9,582 d
CV (%)[c]	3.66	7.11
Topping Height		
Low	3.03 a	10,609 a
High	3.07 a	10,465 a
CV (%)	3.66	7.11
Harvest Treatment		
Last-over	3.03 b	10,216 b
Split last-over	3.04 b	10,279 b
7&3L	3.04 ab	10,712 a
5&5L	3.09 a	10,941 a
CV (%)	3.66	7.11

[a] Philip Morris group designations signify stalk position.
[b] Based on 2005 contract sales pricing.
[c] CV = coefficient of variation.

Table 14. Mean values for leaf length, leaf width, L:W ratio, and leaf area of cultivars and topping heights from the 2002 field experiment.

	Leaf 1[a]							
Cultivar	Length mm		Width mm		L:W Ratio		Area cm^2	
Coker 319	664	b[b]	308	ab	2.18	b	1303	bc
Speight G-168	634	c	291	bc	2.20	b	1216	c
RG H51	711	a	316	a	2.26	ab	1476	a
K 326	651	bc	284	c	2.30	ab	1217	c
NC 71	698	a	308	ab	2.28	ab	1422	ab
Speight NF3	665	b	282	c	2.38	a	1243	c
CV (%)[c]	3.93		5.89		4.40		9.02	
Topping Height								
Low	703	a	312	a	2.27	a	1445	a
High	638	b	281	b	2.28	a	1181	b
CV (%)	3.93		5.89		4.40		9.02	

	Leaf 2							
Cultivar	Length mm		Width mm		L:W Ratio		Area cm^2	
Coker 319	687	b	313	a	2.21	b	1369	b
Speight G-168	646	c	304	ab	2.16	b	1296	b
RG H51	731	a	319	a	2.31	ab	1531	a
K 326	669	bc	292	bc	2.30	ab	1282	b
NC 71	726	a	317	a	2.30	ab	1517	a
Speight NF3	678	bc	284	c	2.40	a	1266	b
CV (%)	3.54		5.57		4.86		7.85	
Topping Height								
Low	719	a	319	a	2.27	a	1507	a
High	659	b	288	b	2.30	a	1246	b
CV (%)	3.54		5.57		4.86		7.85	

Table 14. (cont.) Mean values for leaf length, leaf width, L:W ratio, and leaf area of cultivars and topping heights from the 2002 field experiment.

	Leaf 3							
Cultivar	Length mm		Width mm		L:W Ratio		Area cm^2	
Coker 319	704	b	325	a	2.18	b	1456	bc
Speight G-168	669	c	310	a	2.19	b	1366	cd
RG H51	748	a	326	a	2.32	ab	1603	a
K 326	685	bc	291	b	2.37	a	1308	d
NC 71	745	a	317	a	2.36	a	1555	ab
Speight NF3	694	bc	290	b	2.42	a	1325	cd
CV (%)	3.56		5.43		4.46		8.12	
Low	733	a	326	a	2.27	b	1568	a
High	682	b	291	b	2.36	a	1303	b
CV (%)	3.56		5.43		4.46		8.12	

	Leaf 5							
Cultivar	Length mm		Width mm		L:W Ratio		Area cm^2	
Coker 319	728	b	322	ab	2.28	ab	1516	bc
Speight G-168	680	c	319	bc	2.16	b	1430	bcd
RG H51	762	a	338	a	2.28	ab	1694	a
K 326	702	b	295	e	2.41	a	1361	d
NC 71	766	a	314	cd	2.46	a	1578	ab
Speight NF3	715	b	300	de	2.41	a	1399	cd
CV (%)	3.71		6.41		4.95		8.79	
Topping Height								
Low	741	a	334	a	2.25	b	1628	a
High	709	b	293	b	2.43	a	1365	b
CV (%)	3.71		6.41		4.95		8.79	

Table 14. (cont.) Mean values for leaf length, leaf width, L:W ratio, and leaf area of cultivars and topping heights from the 2002 field experiment.

	Leaf 10							
	Length		Width		L:W		Area	
Cultivar	mm		mm		Ratio		cm^2	
Coker 319	684	b	335	a	2.05	b	1519	ab
Speight G-168	654	c	323	ab	2.04	b	1388	bc
RG H51	714	a	333	a	2.17	ab	1563	a
K 326	655	c	305	c	2.17	ab	1310	c
NC 71	718	a	335	a	2.16	ab	1576	a
Speight NF3	675	bc	312	bc	2.18	a	1332	c
CV (%)	29		13		0.13		7.72	
Topping Height								
Low	690	a	334	a	2.07	b	1514	a
High	676	b	311	b	2.19	a	1382	b
CV (%)	11		7		0.04		7.72	

[a] Leaves were counted starting at the top of the stalk.
[b] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.
[c] CV = coefficient of variation.

Table 15. Mean values for leaf length, leaf width, L:W ratio, and leaf area of cultivars and topping heights from the 2004 field experiment.

	Leaf 1[a]							
Cultivar	Length mm		Width mm		L:W Ratio		Area cm^2	
Coker 319	571	d[b]	244	bc	2.16	b	931	b
Speight G-168	617	bc	264	a	2.22	b	1081	a
RG H51	625	abc	259	ab	2.44	a	1077	a
K 326	599	cd	241	c	2.47	a	958	b
NC 71	650	a	264	a	2.44	a	1143	a
Speight NF3	642	ab	267	a	2.25	b	1126	a
CV (%)[c]	5.67		7.85		16.54		11.86	
Topping Height								
Low	657	a	286	a	2.07	b	1237	a
High	577	b	227	b	2.58	a	868	b
CV (%)	5.67		7.85		16.54		11.86	

	Leaf 2							
Cultivar	Length mm		Width mm		L:W Ratio		Area cm^2	
Coker 319	617	c	268	ab	2.13	b	1091	bc
Speight G-168	647	bc	283	a	2.06	b	1207	abc
RG H51	661	ab	283	a	2.19	b	1235	ab
K 326	640	bc	256	b	2.56	a	1078	c
NC 71	690	a	285	a	2.19	b	1298	a
Speight NF3	656	ab	282	a	2.19	b	1213	abc
CV (%)	4.25		6.03		16.02		8.84	
Topping Height								
Low	679	a	296	a	2.04	b	1321	a
High	625	b	256	b	2.40	a	1052	b
CV (%)	11		7		0.14		8.84	

Table 15. (cont.) Mean values for leaf length, leaf width, L:W ratio, and leaf area of cultivars and topping heights from the 2004 field experiment.

	Leaf 3							
Cultivar	Length mm		Width mm		L:W Ratio		Area cm^2	
Coker 319	640	d	282	bc	2.04	b	1186	cd
Speight G-168	673	bc	296	ab	2.08	b	1309	abc
RG H51	688	b	294	ab	2.17	b	1331	ab
K 326	662	d	271	c	2.38	a	1179	d
NC 71	719	a	300	a	2.21	b	1420	a
Speight NF3	662	bcd	286	abc	2.25	b	1245	bcd
CV (%)	4.14		6.59		14.86		9.86	
Topping Height								
Low	698	a	307	a	2.03	b	1407	a
High	649	b	270	b	2.35	a	1150	b
CV (%)	4.14		6.59		14.86		9.86	

	Leaf 5							
Cultivar	Length mm		Width mm		L:W Ratio		Area cm^2	
Coker 319	664	c	291	bc	2.00	b	1275	c
Speight G-168	692	bc	305	ab	2.00	b	1383	bc
RG H51	715	b	302	ab	2.13	ab	1425	ab
K 326	681	c	284	c	2.25	a	1269	c
NC 71	747	a	316	a	2.13	ab	1550	a
Speight NF3	668	c	289	bc	2.13	ab	1269	c
CV (%)	4.04		6.27		14.62		9.49	
Topping Height								
Low	721	a	313	a	2.13	a	1482	a
High	668	b	283	b	2.08	b	1242	b
CV (%)	4.04		6.27		14.62		9.49	

Table 15. (cont.) Mean values for leaf length, leaf width, L:W ratio, and leaf area of cultivars and topping heights from the 2004 field experiment

	Leaf 10							
Cultivar	Length mm		Width mm		L:W Ratio		Area cm^2	
Coker 319	688	b	302	bc	2.00	a	1371	bc
Speight G-168	676	b	303	bc	2.00	a	1345	cd
RG H51	722	a	309	ab	2.06	a	1464	ab
K 326	674	b	293	cd	2.06	a	1294	cd
NC 71	738	a	320	a	2.00	a	1546	a
Speight NF3	671	b	284	d	2.06	a	1254	d
CV (%)	4.00		5.39		8.70		8.57	
Topping Height								
Low	723	a	313	a	2.00	b	1272	b
High	666	b	290	b	2.06	a	1486	a
CV (%)	4.00		5.39		8.70		8.57	

[a] Leaves were counted starting at the top of the stalk.
[b] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.
[c] CV = coefficient of variation.

Chapter IV

The influence of cultivar, topping height, and harvest treatment on the chemical characteristics of flue-cured tobacco

Abstract

Flue-cured tobacco is harvested as the leaves progressively mature starting with those leaves near the bottom of the plant and ending with the leaves at the top. These different stalk positions differ in chemical composition and are used in different proportions in American blended cigarettes. The objective of this study was to evaluate the effects of cultivar, topping height, and harvest treatment on the cured leaf chemistry of leaves from the upper stalk positions. Field studies were conducted in a split-split plot design. Whole plots, subplots, and sub-subplots consisted of cultivars, topping heights, and harvest treatments, respectively. Cured leaf chemical composition was significantly different among cultivars in two of three years. Total alkaloid content was significantly increased by a low topping height in 2002. Reducing sugar concentration was decreased by the low topping height in 2002. However, reducing sugar content in 2003 and 2004 was significantly higher for the low topping height treatment. A last-over harvest treatment resulted in higher total alkaloid concentrations for the uppermost ten leaves. For the harvest treatments that separated the uppermost ten leaves, the uppermost three or five leaves showed increased total alkaloid concentrations, and reducing sugar concentrations lower than those of the lower seven or five leaves. Total Kjeldahl nitrogen (TKN) concentrations were similar to total alkaloid concentrations in 2003 and 2004. Treatments with high total alkaloid concentration generally also showed elevated TKN percentages. Total alkaloid and TKN concentrations were higher in tobacco from

the top stalk position than in tobacco from the middle of the stalk. Conversely, reducing sugar concentration decreased in the top stalk position. These differences in chemical composition are important to the blending processes used in the manufacture of American blend cigarettes, and are lost when stalk positions aren't properly separated.

Introduction

The chemical composition of tobacco has a direct effect on the usability of tobacco to manufacturers of tobacco products. The two primary chemical constituents evaluated in flue-cured tobacco are total alkaloid and reducing sugar concentrations. Total alkaloid concentration is used as an indicator of nicotine content. Reducing sugar concentrations are higher in flue-cured tobacco than in other tobacco types. These high reducing sugar concentrations are responsible for the smoke flavor characteristics of flue-cured tobacco.

The chemical composition of cured tobacco can be affected by genetics, environment, and cultural practices. One cultural practice, such as topping height, can influence the chemical composition of the cured tobacco. As topping height is increased total alkaloid, and consequently nicotine content in the leaves is generally reduced. Conversely as topping height is increased reducing sugar content is increased (Campbell et al. 1982, Elliot 1970, Brown and Terrill 1973, Gooden et al. 1976, and Miner 1980). Low topping heights also remove the leaves that possess the characteristics particular to tip grade tobacco, which companies currently desire.

Harvest rate effects on flue-cured tobacco can be unpredictable (Miner 1980, Brown and Terrill 1973, Gooden et al. 1976). Chaplin (1975) found that cultivar can influence the effect of harvest rate on flue-cured tobacco leaf chemistry. Gooden et al. (1976) and Suggs et al. (1989) found no effect of harvest rate on chemical composition of cured leaves. Harvest rate affects chemical composition of tobacco as related to stalk position. Tobacco harvested in fewer passes through the field possessed chemical characteristics of tobacco from low stalk positions as a result of blending of the stalk positions while tobacco harvested multiple times reflected the chemical characteristics of the differing stalk positions. The objective of this study was to evaluate the effect of cultivar, topping height, and harvest treatment on the chemical composition of flue-cured tobacco from the upper stalk positions.

Materials and Methods

Field experiments were conducted at the Virginia Polytechnic Institute and State University Southern Piedmont Agricultural Research and Extension Center near Blackstone, Virginia in 2002, 2003, and 2004. Harvest treatments included treatments that would minimize tip production as well as treatments that would maximize production of tip grade tobacco. Two topping heights were evaluated to increase the likelihood of producing tip leaves, a sub-classification of leaves in the B group being short in length, narrow in width, and heavy in body. The six cultivars were selected to evaluate plants with different growth characteristics and popularity among growers.

Field studies were conducted as a split split-plot design with four replications. Whole plots consisted of six cultivars, which were NC 71, RG H51, Speight G-168, Speight NF-3, Coker 319, and K 326. Subplots were two topping heights. Plants were topped to 20 and 25 leaves in 2002, 16 and 20 leaves in 2003, and 18 and 22 leaves in 2004. Plant topping heights varied each year because of seasonal growing conditions. The maximum number of marketable leaves available in 2003 and 2004 were 20 and 22 leaves, respectively. Plants were topped when a majority of plants in all plots reached the desired number of leaves. Sub-subplots consisted of four harvest treatments which differed only in their treatment of the uppermost ten leaves on the plant. Ten leaves remained on the plant after the first two harvests in the low topping height treatments whereas ten leaves remained on the plant after completion of the third harvest in the higher topping height treatments.

Two of the four harvest treatments (Figure 1) were Last-Over, the last ten leaves on the plant harvested as one stalk position and Split Last-Over, where the last ten leaves were harvested at one time and then separated into the first seven and the uppermost three leaves. In the Seven and Three Leaves (7&3L) treatment, the last ten leaves on the plant were harvested at different times. The first seven leaves were harvested prior to the uppermost three. The uppermost three leaves were harvested in a subsequent final harvest when the leaves were ripe. In the Five and Five Leaves (5&5L) harvest treatment, the last ten leaves on the plant were harvested at different times. The first five leaves were harvested prior to the uppermost five. The uppermost five leaves were harvested in a subsequent final harvest.

Production practices not affected by treatments followed those outlined by Reed et al. (2002). Plots were harvested by hand when a majority of plots were judged to be at optimum ripeness. This resulted, in some instances, in the over-ripening of the earliest maturing cultivars (particularly Coker 319) and the potential for harvest of under-ripe tobacco from the late-maturing cultivars. Cured plots were separated and weighed by harvest. Samples were taken at the time the plots were weighed in order to collect cured leaf chemistry data. A Foss NIR Systems (Foss North America, Eden Prairie, MN) near infrared spectroscopy (NIRS) unit was used to determine percent total alkaloids, percent reducing sugars, and total Kjeldahl nitrogen (McClure and Williamson, 1986). Analysis of variance was conducted using PROC GLM (SAS Institute, 1987). Treatment means were separated using Fisher's LSD test (Gomez and Gomez, 1984). Plots were analyzed by stalk position.

Results and Discussion

Chemical analysis reflects the chemical composition of the uppermost ten leaves, separated by stalk position. The upper-middle stalk position refers to uppermost ten leaves for the last-over harvest treatment (Figure 2). In the split last-over and 7&3L harvest treatments, the upper-middle stalk position refers to the lower 7 leaves of the uppermost ten leaves on the plant (Figure 2). The upper-middle stalk position represents the lower 5 of the uppermost ten leaves on the plant, in the 5&5L harvest treatment. Remaining leaves were included in the top stalk position (Figure 2). The last-over harvest treatment did not include a top stalk position as the uppermost ten leaves were included with the upper-middle stalk position (Figure 2). There was no top stalk position for the last-over harvest treatment. The uppermost ten leaves were combined into one stalk position for this treatment and are described as the upper-middle stalk position here. Total Kjeldahl nitrogen was not determined in 2002.

Total Alkaloids - Cultivar

There were significant differences among cultivars for total alkaloid content of the upper-middle stalk position in all three years. Coker 319 and NC 71 produced the highest total alkaloid concentrations among cultivars in 2002, 4.32% and 4.35%, respectively (Table 1). The Speight cultivars G-168 and NF3 produced high total alkaloid concentrations in both 2003 and 2004 (Table 2 and 3). Differences among cultivars for total alkaloid content of the top stalk position were significant only in 2004

(Table 3). A total alkaloid concentration of 3.12% in K 326 was significantly lower than total alkaloids in all other cultivars.

Topping Height

The influence of topping height on total alkaloid concentration of the upper-middle stalk position was significant only in 2002, when the low topping height produced higher total alkaloid levels (Table 1). This is similar to results observed by Campbell et al. (1982), Elliot (1970), Gooden et al. (1976), and Miner (1980). As topping height is decreased alkaloids become more concentrated in lower number of leaves. The 4.86% total alkaloid value for the low topping height was significantly higher than the 4.20% value for the high topping height (Table 1). Similarly for the top stalk position, the low topping height produced significantly higher total alkaloid levels than the high topping height, in 2002 and 2003 (Table 1 and 2). Differences were not significant in 2004.

Harvest Treatment

The last-over harvest treatment resulted in significantly higher total alkaloid concentrations than all other treatments for the upper-middle stalk position in 2002 and 2003. This was also evident in 2004, however, the difference was not significant. In 2003 there were significant differences for total alkaloids among harvest treatments for the upper-middle stalk position (Table 2). NC 71 had a total alkaloid concentration of 2.38%. RG H51 and K 326 had concentrations of 2.0% 1and 2.02% respectively. The last-over and split last-over harvest treatments resulted in significantly higher total alkaloid concentrations than the 7&3L and 5&5L treatments (Table 2). The 7&3L and 5&5L harvest treatments both resulted in a 3.42% total alkaloid concentration while the concentration of the split last-over treatment was 3.30% in 2004 (Table3).

Of particular importance is the difference in total alkaloid content of the last-over treatment when compared to the two stalk positions of the other harvest treatments. The total alkaloid concentration of the last-over treatment lies between the concentrations of the upper-middle and top stalk positions for the remaining harvest treatments. When stalk positions are combined, this variation is lost. It is for this reason that tobacco purchasers prefer to have the stalk positions separated. It should also be noted that as a result of nitrogen leaching, the total alkaloid content of tobacco from all treatments was much lower in 2003 than in 2002 and 2004.

Reducing Sugars - Cultivar

Reducing sugar concentrations were significantly different among cultivars in 2003 and 2004. Coker 319, RG H51, Speight G-168, and K326 produced the highest levels of reducing sugars in 2003 for the upper middle stalk position (Table 2). Reducing sugar concentration for Speight G-168 was much lower for the top stalk position. The lowest value for percent reducing sugars of the top stalk position was produced by NC 71 with a concentration of 8.46 (Table 2) Reducing sugar concentration of K 326 was highest among cultivars for both stalk positions in 2004, while Speight G-168 and Speight NF-3 had the lowest concentrations (Table3). K 326 produced the highest reducing sugar concentration, 12.82% while the lowest value recorded was for Speight G-168 at 8.26% (Table3).

Topping Height

The upper-middle stalk position had significant differences for percent reducing sugars between topping heights in all three years. The low topping height in 2002 resulted in a lower reducing sugar concentration than the high topping height (Table 1).

This is similar to results of Gooden et al. (1976) and Miner (1980). Conversely, in 2003 and 2004 the high topping height treatment resulted in the lower reducing sugar concentration of the two treatments (Tables 2 and 3). These differences are likely attributed to differences among the growing seasons and have been found in the past (Arsenault 1986).

Similar to the upper-middle stalk position, the top stalk position showed significantly lower reducing sugar concentration for the low topping height in 2002 (Table 1). Differences in reducing sugar concentration between topping heights were not significant in 2003 and 2004. In 2003 and 2004 increasing topping height and separating the upper stalk positions resulted in lower reducing sugar concentration. Reducing sugar concentration was lower in leaves located near the top of the plant than in the leaves from the middle of the stalk.

Harvest Treatment

There were significant differences among the harvest treatments for reducing sugar concentration for the upper-middle stalk position in 2003 and 2004 (Tables 2 and 3). The treatments that separated the upper stalk position resulted in higher reducing sugar concentrations than the last-over treatment. This is a result of the lower concentrations at the top of the stalk. When the tobacco was combined reducing sugar concentration was in effect diluted.

There were significant differences among harvest treatments for the top stalk position only in 2003 (Table 2). The 7&3L treatment had the lowest concentration followed by the 5&5L treatment. This again indicates that position on the stalk influences reducing sugar concentration. As with total alkaloid content it is important to compare the reducing sugar content of the last-over harvest treatments to both stalk positions of the remaining harvest treatments. It is these differences in cured leaf chemistry that make separation of stalk positions important to tobacco purchasers

Total Kjeldhal Nitrogen - Cultivar

Total Kjeldhal Nitrogen (TKN) data was only collected in 2003 and 2004. For the upper-middle stalk position there were significant differences for TKN concentration among cultivars in both years (Tables 2 and 3). NC 71, Speight G-168, and Speight NF-3 had the highest concentrations while K 326 had the lowest in 2003 (Table 2). TKN analysis results in 2004 were similar to results in 2003 for the upper-middle stalk position. Coker 319, NC 71, Speight G-168, and Speight NF-3 had the highest concentrations and again K 326 had the lowest (Table3). These same cultivars had the highest TKN concentrations for the top stalk position in both years as well.

Topping Height

Between topping heights there were significant differences in both years for both stalk positions. For the upper-middle stalk position the TKN concentration of the low topping height treatment was significantly lower than the high treatment in both years (Tables 2 and 3). Conversely, for the top stalk position the high topping height treatment had the lower TKN concentration in both years (Tables 2 and 3). This is in agreement with findings by Brown and Terrill (1973) Gooden et al. (1976) and Miner (1980).

Harvest Treatment

Similar to what was observed for total alkaloid content, TKN concentration was higher in the tobacco from the top of the stalk than in the leaves from the middle of the stalk. For the upper-middle stalk position, among cultivars the last-over harvest treatment had a significantly higher TKN concentration than all others in both years (Tables 2 and 3). The TKN concentration of the 5&5L treatment was significantly lower than the split last-over and 7&3L treatments. The inclusion of two more leaves from near the top of the plant for these treatments increased the TKN concentration for the upper-middle stalk position.

For the top stalk position differences in TKN concentration were significant in both years (Tables 2 and 3). The 7&3L treatment resulted in the greatest TKN concentration in both years. The three leaves included in this stalk position were located at the very top of the stalk, where TKN concentration will be the highest. The last-over harvest treatment resulted in a TKN concentration that fell between the upper-middle and top stalk positions of the other three harvest treatments. This reinforces the importance of proper stalk position separation to the tobacco purchaser.

Summary

It was observed that both total alkaloid and total Kjeldahl nitrogen concentration are higher at stalk positions near the top of the plant. This is compared to those concentrations from stalk positions at the middle of the plant. Data from the lower stalk positions are not presented. Reducing sugar concentration decreased from the middle of the plant to the top. When harvest treatments that combined the upper most three leaves into one stalk position were compared to a treatment that combined the uppermost five leaves into one stalk position, these trends were reinforced. It was also observed that there are differences in chemical composition between the upper-middle and top stalk positions. When these positions are combined, the tobacco purchaser loses the ability to use these differences in their blending processes.

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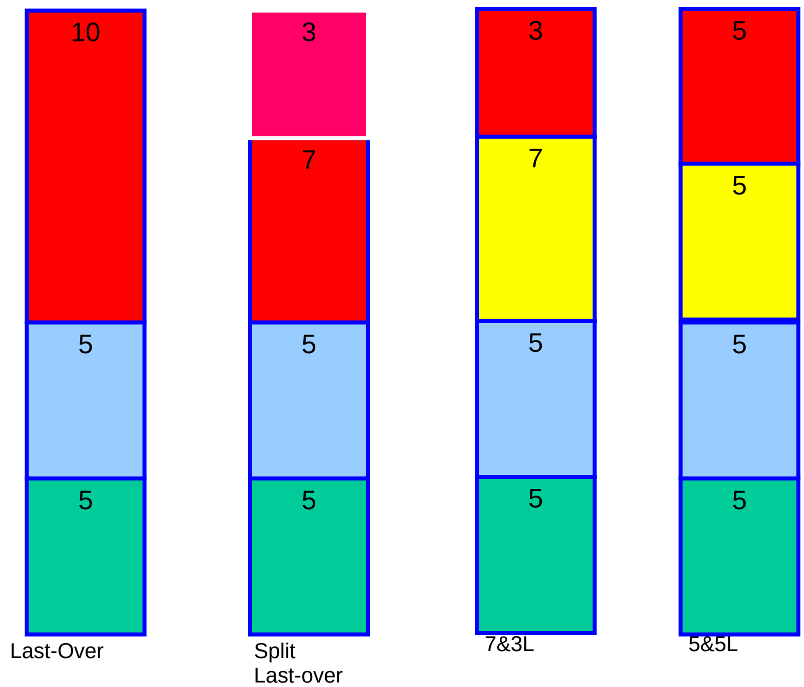

Figure 1. Diagrammatic representation of the four harvest treatments for the low topping height treatment. Numbers indicate the number of leaves removed with each harvest. Alike colors were harvested at the same time. The first three harvests in the high topping height treatment were five-leaf harvests compared to the first two harvests in the lower topping height treatment.

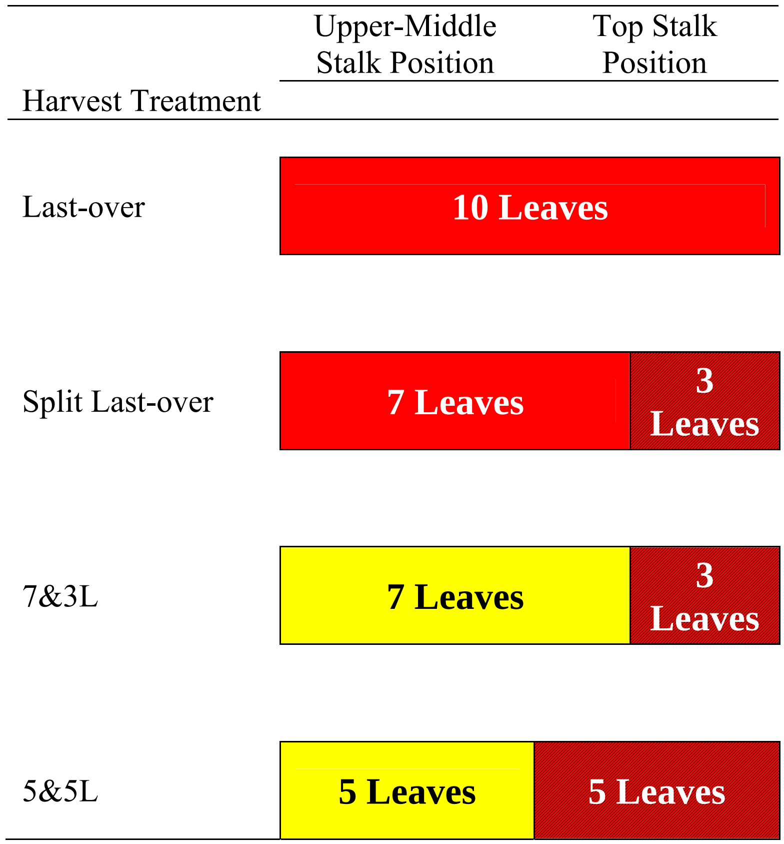

Figure 2. Diagram showing the number of leaves from the last ten leaves on the plant, included in each stalk position used for chemical analysis. Colors represent harvest date. Non-shaded areas include the upper-middle stalk position. The shaded areas include the top stalk position.

Table 1. Mean total alkaloid (TA) and reducing sugar (RS) concentrations of the uppermost ten leaves of cultivars, topping heights, and harvest treatments from the 2002 field experiment.

	Stalk Positions			
	Upper-Middle TA	Top TA	Upper-Middle RS	Top RS
Cultivar	%			
Coker 319	4.32 a[a]	4.68 a	9.17 a	9.56 a
Speight G-168	4.11 b	4.46 a	8.22 a	6.49 a
RG H51	4.31 a	4.68 a	7.24 a	7.14 a
K 326	3.95 c	4.32 a	8.86 a	8.19 a
NC 71	4.35 a	4.63 a	6.48 a	6.17 a
Speight NF3	4.28 a	4.47 a	5.94 a	5.76 a
CV (%)[b]	7.54	6.53	25.75	22.10
Topping Height				
Low	4.33a	4.86a	6.22b	5.96 b
High	4.10b	4.20b	8.95a	8.28 a
CV (%)	7.54	6.53	25.75	22.10
Harvest Treatment				
Last-over	4.37 a	NA	7.34 a	NA
Split last-over	4.19 b	4.44 c	8.12 a	7.05 b
7&3L	4.15 b	4.64 a	7.28 a	6.33 c
5&5L	4.15 b	4.53 b	7.59 a	7.92 a
CV (%)	7.54	6.53	25.75	22.10

[a] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.
[b] CV = coefficient of variation.

Table 2. Mean total alkaloid (TA), reducing sugar (RS), and total Kjeldahl nitrogen (TKN) concentrations of the uppermost ten leaves of cultivars, topping heights, and harvest treatments from the 2003 field experiment.

	Stalk Positions					
	Upper-Middle TA	Top TA	Upper-Middle RS	Top RS	Upper-Middle TKN	Top TKN
Cultivar	%					
Coker 319	2.19 b[a]	2.63 a	15.44 b	12.53	1.85 bc	2.18
Speight G-168	2.33 a	2.83 a	16.64 a	8.76	1.87 b	2.50
RG H51	2.01 c	2.42 a	15.59 b	10.47	1.81 c	2.32
K 326	2.02 c	2.72 a	15.27 bc	10.67	1.74 d	2.31
NC 71	2.38 a	2.62 a	11.99 d	8.46	1.99 a	2.34
Speight NF3	2.33 a	2.95 a	14.89 c	9.06	1.86 bc	2.40
CV (%)[b]	14.18	10.04	9.40	14.09	7.47	6.33
Topping Height						
Low	2.21 a	2.99 a	15.69 a	10.02 a	1.76 b	2.41 a
High	2.21 a	2.37 b	13.10 b	9.61 b	1.95 a	2.29 b
CV (%)	14.18	10.04	9.40	14.09	7.47	6.33
Harvest Treatment						
Last-over	2.39 a	NA	12.32 d	NA	2.04 a	NA
Split last-over	2.28 b	2.41 c	13.57 c	11.07 a	1.90 b	2.14 c
7&3L	2.10 c	2.99 a	15.60 b	8.25 c	1.77 c	2.61 a
5&5L	2.09 c	2.69 b	16.08 a	10.15 b	1.72 d	2.32 b
CV (%)	14.18	10.04	9.40	14.09	7.47	6.33

[a] Values with the same letter are not significantly different based on Fishers protected LSD at $P = 0.05$.

[b] CV = coefficient of variation.

Table 3. Mean total alkaloid (TA), reducing sugar (RS), and total Kjeldahl nitrogen (TKN)concentrations of the uppermost ten leaves of cultivars, topping heights, and harvest treatments from the 2004 field experiment.

	Stalk Positions					
	Upper-Middle TA	Top TA	Upper-Middle RS	Top RS	Upper-Middle TKN	Top TKN
Cultivar	%					
Coker 319	3.30 ab[a]	3.42 a	11.81 bc	8.36 c	2.38 b	2.47 b
Speight G-168	3.43 a	3.47 a	10.20 d	8.26 c	2.64 a	2.72 a
RG H51	3.09 cd	3.45 a	12.78 b	9.40 bc	2.29 b	2.48 b
K 326	2.96 d	3.12 b	14.30 a	12.82 a	2.33 b	2.53 b
NC 71	3.18 bc	3.44 a	12.28 b	9.88 b	2.38 b	2.57 b
Speight NF3	3.35 ab	3.39 a	10.63 cd	9.58 bc	2.58 a	2.57 b
CV (%)[b]	9.39	7.08	21.10	21.40	7.75	6.92
Topping Height						
Low	3.20 a	3.37 a	13.25 a	10.22 a	2.40 b	2.64 a
High	3.23 a	3.39 a	10.75 b	9.22 a	2.46 a	2.48 b
CV (%)	9.39	7.08	21.10	21.40	7.75	6.92
Harvest Treatment						
Last-over	3.31 a	NA	11.11 b	NA	2.50 a	NA
Split last-over	3.24 ab	3.30 b	10.81 b	10.03 a	2.45 a	2.49 b
7&3L	3.19 ab	3.42 a	12.62 a	9.57 a	2.43 ab	2.60 a
5&5L	3.12 b	3.42 a	13.46 a	9.56 a	2.36 b	2.59 a
CV (%)	9.39	7.08	21.10	21.40	7.75	6.92

[a] Values with the same letter are not significantly different based on Fishers protected LSD at *P* = 0.05.

[b] CV = coefficient of variation.