Influence of Nitrogen Rate, Harvest Frequency, Lower Leaf Management, and Chemical Topping on Mammoth Cultivars of Flue-Cured Tobacco

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(Abstract)

Mammoth cultivars of tobacco do not flower under normal production conditions. A field management system must be devised for these cultivars to optimize agronomic traits and chemical constiuents of the cured leaf. Field experiments were conducted at the Southern Piedmont Agricultural Experiment Station near Blackstone, Virginia in 1987 and 1988 to determine the influence of nitrogen rate, harvest frequency, and time and number of basal leaf removal on several agronomic and chemical properties of a mammoth cultivar of flue-cured tobacco. The feasibility of chemically topping two mammoth cultivars was also investigated. Increasing nitrogen rates increased values per hectare by \$176 and total alkaloids by 0.5% in 1987. Increasing the number of harvest increased percentage lugs (X) and reducing sugars for stalk position B in 1988 but decreased reducing sugars for stalk positions A and C in 1988. Delaying leaf removal increased yield and values per hectare by 141 kg ha^{-1} and \$84, respectively, and decreased lug production in 1987 and 1988. Total alkaloids

decreased by 0.7% with delayed leaf removal in 1987. Delayed leaf removal increased reducing sugars at stalk position A by 2% in 1988. Removing fewer basal leaves increased yields by 115 kg ha^{-1}, values per hectare, and percentage smoking leaf (H) for both years. Alkaloids for stalk position B increased with fewer basal leaves removed in 1988. Decreased basal leaf removal decreased plant height by 9 cm, percentage leaf (B), and reducing sugars in stalk positions A, B, and D in 1988. Delaying basal leaf removal and decreasing harvest frequency increased the percentage of cutters (C). Percentage smoking leaf increased with nitrogen rate and removal of fewer basal leaves. Chemical topping created taller plants with more leaves, narrower tip leaves, lower total alkaloids, and equal or higher reducing sugars relative to hand topping. Tip leaves from chemically topped plants were 6 to 8 cm shorter than hand-topped plants in 1987. Maleic hydrazide treatments resulted in 429 to 700 kg ha^{-1} lower yields and lower values than hand topping and 6 more suckers than all other treatments. The fatty alcohol / maleic hydrazide treatment produced 380 kg ha^{-1} higher yields and grade indices lower than the hand-topped control in 1987. Above normal nitrogen rate, 3 or 5 time harvest, removal of 4 to 6 leaves at topping or via senescence, and chemical topping with Prime+ or fatty alcohol / maleic hydrazide tank mix provided the best field management system for mammoth cultivars under the conditions of this study.

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Chapter I
Introduction

Incorporation of the mammoth gene into acceptable genetic backgrounds may provide a great potential for flue-cured tobacco production (30). The mammoth or non-flowering gene characteristicly causes day-neutral tobacco to flower only under short day photoperiods, thereby increasing the number of leaves that may be produced during a normal growing season (19). Increasing the number of leaves produced provides potential yield increases since the leaf is the economically important part of the tobacco plant (5).

Demand for flue-cured tobacco from lower stalk positions has declined and a large amount of downstalk tobacco has accumulated in the Flue-cured Tobacco Cooperative Stabilization Corporation inventory (19). Use of mammoth varieties may allow production of greater percentages of upstalk leaf and decreased percentages of less desirable basal leaves.

Chaplin (5) noted that quality decreased as leaf numbers increased on 'Hicks Mammoth'. However, he concluded that the inferior quality of mammoth varieties was not directly related to the mammoth gene.

Wernsman and Matzinger (30) allowed mammoth varieties to produce additional upstalk leaves to substitute for removed basal leaves. They found higher yields and equal or superior leaf quality when mammoth varieties were managed as normal varieties. However, above-normal yields, reduced alkaloids, and higher concentrations of reducing sugars were found when mammoths were allowed to produce four additional leaves after the four bottom leaves had been removed.

Jones and Terrill (19) compared two day-neutral cultivars with their mammoth counterparts. The mammoth varieties were topped four leaves higher than the day-neutral varieties. The bottom four leaves were removed and discarded. They reported that 'mammoth NC 2326' produced higher yields than normal 'NC 2326.' 'Mammoth Speight G-28' produced lower yields than the day-neutral counterpart. Total alkaloids and reducing sugars were lower for the mammoths than for their respective day-neutral counterparts.

King (20) noted that yield, grade index, and value increased with topping height. However, total alkaloids, reducing sugars, and total nitrogen decreased as the number of leaves per plant increased. King also reported that the sugar-to-total alkaloid ratio increased with increased leaf numbers per plant.

The objectives of this study were:

1) to determine the influence of nitrogen rate,

harvest frequency, time of basal leaf removal, and number of basal leaves discarded on yield, quality index, value per hectare, leaf maturity, leaf grade, and leaf chemistry of NC 27 NF,

2) to determine the influence of chemical topping with Prime+, fatty alcohol, and maleic hydrazide alone and in various combinations on yield, quality index, value per hectare, leaf maturity, leaf grade, and leaf chemistry of NC 22 NF and NC 27 NF.

Chapter II

Literature Review

Introduction of the mammoth gene into acceptable genetic backgrounds created one of the greatest potential management advances for tobacco production in recent years. The mammoth or non-flowering characteristic causes day-neutral plants to flower only under short-day photoperiods, reducing premature flowering, synchronizing topping and sucker control treatments, and increasing the number of leaves produced during a normal growing season. Demand for flue-cured tobacco from lower stalk positions has declined in recent years since large amounts of downstalk tobacco have accumulated in the Flue-Cured Tobacco Cooperative Stabilization Corporation inventory (1, 19). However, reducing the number of downstalk leaves harvested without subsequent decreases in yield and quality is feasible with mammoth cultivars.

Mammoth Management

Higher yields, fewer suckers, reduced alkaloids and inferior quality were reported when mammoth cultivars were allowed to produce greater leaf numbers per plant than day-neutral cultivars (21, 22). Chaplin (2) noted that quality index decreased as leaf numbers increased on 'Hicks

Mammoth'. Chaplin concluded that the inferior quality of mammoth varieties was not directly related to the mammoth gene.

Mammoth management tests were conducted by Wernsman and Matzinger (30). Mammoth cultivars were allowed to produce additional upstalk leaves to substitute for basal leaves that had been removed. Higher yields and equal or superior quality indices resulted when mammoth genotypes were permitted to produce the same number of leaves as normal cultivars. However, above-normal yields, reduced alkaloids, and higher concentrations of reducing sugars were obtained when mammoths were allowed to produce four additional leaves and the bottom four leaves were removed.

Jones and Terrill (19) compared two day-neutral cultivars with their mammoth counterparts. Day-neutral plants were topped at 18 leaves and mammoth plants were topped at 22 leaves but the bottom four leaves were removed and discarded. They reported that 'mammoth NC 2326' produced higher yields than day-neutral 'NC 2326' but 'Mammoth Speight G-28' produced lower yields than the day-neutral counterpart. Total alkaloids and reducing sugars were lower for the mammoth cultivars than for their respective day-neutral counterparts. The higher yielding mammoth produced higher reducing sugar concentrations than the lower yielding mammoth variety.

King (20) investigated the influence of varying the topping height of mammoth varieties on yield, quality, and economic value. Yield, grade index, and value increased as topping heights increased from 14 to 26 leaves. However, total alkaloids, reducing sugars, and total nitrogen decreased as the number of leaves per plant increased, respectively. King also reported that the sugar-to-alkaloid ratio increased with increased leaf numbers per plant. King concluded from these findings that the cultivar NC 22 NF can produce up to 26 leaves without any significant decline in desired leaf chemistry.

Nitrogen Rates

Nitrogen availability generally has the greatest influence on tobacco growth, curability, and usability compared to other nutrients required for tobacco production (28). Campbell, et al. (4) studied the effect of nitrogen rate on dry weight and nicotine accumulation of the cured leaf. Several varieties of flue-cured tobacco were used during the three years of the study and the results were essentially the same for all varieties. Increasing nitrogen rates above 112 kg ha^{-1} did not significantly affect nicotine levels or dry weight accumulation. In a similar study Miner (23, 24) also noted no increase in yield or nicotine levels with increasing nitrogen rates above the normally recommended rate. However, Miner reported that reducing sugar levels and quality index were lower with higher nitrogen rates. Weybrew, Wan Ismail, and

Long (31) investigated the effect of nitrogen rate on yield, grade index, nicotine, and reducing sugars. No yield differences were found with varying nitrogen rates, but higher grade indices, higher nicotine levels, and lower reducing sugar levels occurred when above normal nitrogen rates were used. Weybrew et al. concluded that the optimum nitrogen rate for yield, quality index, and leaf chemistry would either be slightly below or equal to the normally recommended rate. Congleton (9) found that yields increased, reducing sugar decreased, and quality index and alkaloid levels were not significantly changed when nitrogen rate was increased 34 kg ha^{-1} above the normal rate.

Harvest Frequency

Increased labor costs and decreased labor availability during recent years have increased interest in reducing harvest frequencies (2, 16, 17). However, decreasing the number of harvests also caused concern over the ripeness of tobacco when harvested and the subsequent suitability of the cured leaf for the manufacture of smoking products. Ripe tobacco reportedly cures easier, responds better to aging, and provides a more flavorful, palatable smoke (25).

Ripeness is a subjective judgement and is not easily defined. Some characteristics of ripening tobacco include: 1) leaves drooping away from the stalk, 2) leaves becoming velvety, 3) leaf color fading from green to yellow, and 4) leaf midrib whitening from the base outward to the leaf tip (32).

Brown and Terrill (2, 3) compared a normal or five time harvest with a one-time harvest for VA 115 and Coker 319. All plots were harvested in two-leaf sub-units and tagged for future analysis. Higher yields, values, prices per cwt, and nicotine levels were obtained with a normal harvest. On the other hand, some immature, ripe, and overmature tobacco was harvested within the one-time harvest. When the upper and lower leaves of the one-time harvested plots were disregarded, the remaining leaves compared favorably with leaves from multiple harvested plots. Miner (23, 24) also reported multipass harvesting provided slightly higher yields and quality.

Other workers studied three multipass harvest schedules: 1) one week prior to physiological ripeness, 2) at physiological ripeness, and 3) one week after physiological ripeness (25, 32). Higher yields were obtained, but poor leaf chemistry and low grade indices were prevalent, where tobacco was harvested before reaching ripeness or maturity. On the other hand, lower yields, higher grade indices, and more acceptable nicotine and reducing sugar levels were obtained when tobacco was harvested when ripe or slightly overripe. Increased nicotine levels were explained by a lingering synthesis and accumulation of nicotine as the leaf was allowed to ripen. Higher grade indices resulted from increased leaf body and texture caused by the ripening process (25, 32).

Walker (29) conducted harvests starting at six weekly intervals beginning on July 26. Tobacco harvested at the earliest starting date had the lowest yield and quality index. Tobacco harvested at the fourth starting date had the highest yield and quality index. In fact, their data formed somewhat of a bell-shaped curve with the tobacco harvested at the fourth starting date providing the peak for yield and quality index. No differences in nicotine or reducing sugars were associated with the delayed harvests.

Gwynn (16) divided the tobacco plant into six equal sections (starting at the bottom of the stalk) and harvested each section separately. Using these sections, he also devised five harvest schemes:

1) a two time harvest - harvested when sections two and five were ripe,
2) a two time harvest - harvested when sections three and six were ripe,
3) a three time harvest - harvested when sections two, four and six were ripe,
4) a three time harvest - harvested when sections one/two, three/four, and five/six were ripe, and
5) a three time harvest - harvested when sections one/two and three/four were ripe and when section six was one week past ripe.

No differences in yield were observed among treatments. The only significant differences were higher acre values, higher reducing sugars, and lower nicotine for the normal harvest and treatment one relative to the other treatments in year one of the study. In year two, no differences were obtained among treatments. From these studies, Gwynn concluded that modified harvests may approach conventional harvest in yield, quality, price, and leaf chemistry. However, he indicated that the effectiveness of a modified harvest system may depend greatly on the variety and environmental conditions.

Gwynn (17) conducted a second study using four flue-cured tobacco varieties and three harvest schedules (one-harvest, topped at 12 leaves; two-harvest, topped at 14 leaves; and three-harvest, topped at 19 leaves). Yields and reducing sugars decreased, but total alkaloids increased with decreasing number of harvests.

Lower Leaf Removal

Collins and Miner (6, 7) investigated the feasibility of not harvesting the basal four leaves of tobacco. The lower four leaves are considered the least desirable and, in fact, these downstalk leaves received little or no price support in 1980 (6, 7). Collins and Miner observed that not harvesting four basal leaves decreased yield, but had little effect on quality index. They also reported that yields were not decreased as much if the leaves were removed and discarded at the button stage as when the leaves were allowed to senesce and burnoff the stalk. In fact, they concluded removing these leaves may have several benefits: decreased occurrence of blue mold, decreased interference with harvest activities, and decreased drain on the plant's resources.

Chemical Topping

Mammoth cultivars practically eliminate premature flowering and increase synchronization of topping and sucker control (30). Due to the uniform growth and lack of early flowering of mammoth or non-flowering cultivars, chemical topping may become a means of topping and controlling suckers for these varieties. Chemical topping is not a currently recommended practice for flue-cured tobacco production, however, some work has been done to evaluate the effectiveness of chemical topping (18).

Flue-cured tobacco should be topped when 18 to 20 harvestable leaves have developed. Generally, these leaves are produced by the prebutton stage, facilitating early topping and chemical topping. Chemical topping is usually performed before floral emergence. The floral parts of a tobacco plant drain the plant of resources necessary for leaf development and, therefore, decrease yields and quality. However, yield and quality levels may be significantly increased if the plants are chemically topped prior to flower formation (18).

Steffens and Mckee (27) conducted chemical topping experiments using a fatty alcohol (1-Decanol) on 'Maryland 64' in 1967. They found that the fatty alcohol provided excellent control of flowering and sucker production if the chemical was applied during the button stage. They also noted that chemically topped tobacco produced yields, values per hectare, and leaf chemistry equal to or greater than those produced by conventionally topped tobacco.

Schaeffer and Sharpe (26) conducted a similar study using N^6 -benzyladenine to break apical dominance followed by N^6 -methylpurine for sucker control. They noted chemically treated plants had excellent sucker control. Yeld, value and leaf chemistry were not evaluated.

Coulson (10) compared using maleic hydrazide on both topped and non-topped plants versus hand-suckering on similar plants. Failing to hand top plants of day-neutral cultivars reduced alkaloid levels and increased sugar-to-alkaloid ratios but had no significant effects on reducing sugar levels. In fact, a similar study conducted by DeBaets (11) showed that not topping day-neutral cultivars decreased nicotine levels in wrappers and tips by 50% or more. When maleic hydrazide was used for chemical topping and sucker control, alkaloid levels were even lower, and sugar-to-alkaloid ratios were slightly higher than the levels for any of the other treatments.

Several other researchers have evaluated the influence of topping time and topping height on chemical and physical properties of day-neutral flue-cured tobacco. Generally, these studies show increasing topping height increased yields and decreased grades and nicotine levels (8, 12, 13, 14, 15). According to Elliot (15), topping stimulates nicotine production in the fibrous roots. Therefore, earlier topping allows a longer period of time for accumulation of nicotine in the leaves. In fact, prior to topping time, little nicotine accumulates in the leaves.

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Chapter III

Influence of basal leaf removal on agronomic traits and chemical constituents of NC 27 NF

Abstract

Accumulations of tobacco from lower stalk positions in Flue-Cured Tobacco Cooperative Stabilization Corporation has created an interest in decreasing production of priming and lug grades and increasing production of cutter and leaf grades. A field study was conducted at the Southern Piedmont Agricultural Experiment Station near Blackstone, Virginia to determine the influence of basal leaf removal on mammoth varieties of flue-cured tobacco. The experiment was designed as a randomized complete block with four replications. Treatments consisted of removing and discarding 0, 4, 6, or 8 basal leaves from the plants in each plot at topping time. Plants were topped to give twenty harvestable leaves. Quality index, leaf maturity, and percentage of primings decreased, and percentage of cutters increased as the number of basal leaves removed increased from 0 to 8. Reducing sugars increased, total alkaloids declined, and sugar-to-alkaloid ratios increased as more basal leaves were removed. Plant height also increased with increasing number of basal leaves removed. The number of leaves to remove for best quality, yield, and

leaf chemistry would be four to six. If more than six leaves were removed, quality declined. If fewer than four leaves were removed, total alkalods dropped well below acceptable concentrations.

Introduction

Mammoth varieties of flue-cured tobacco are photoperiod sensitive and only flower during short day lengths. Therefore, these varieties may produce up to forty or fifty leaves before flowering (14). This growth habit provides the opportunity to produce more upstalk leaves per plant and eliminate the less desirable basal leaves. Demand for flue-cured tobacco from down-stalk positions has declined since the mid 1970's. Large amounts of down-stalk tobacco have accumulated in the Flue-Cured Tobacco Cooperative Stabilization Corporation inventory (1, 9).

Higher yields, fewer suckers, reduced alkaloids and inferior quality were reported when mammoth cultivars were allowed to produce greater leaf numbers per plant (11, 12). Chaplin (3) noted that quality decreased as leaf numbers increased on 'Hicks Mammoth'. He concluded that the inferior quality of mammoth varieties was physiological and not directly related to the mammoth gene.

Mammoth management tests were conducted by Wernsman and Matzinger (14). Mammoth cultivars were allowed to produce additional up-stalk leaves to substitute for basal leaves that were removed and discarded. They observed above-normal-yields, reduced alkaloids, and higher reducing sugar concentrations when four basal leaves were removed and four additional leaves were produced.

Jones and Terrill (9) compared 'NC 2326 and Speight G-28 with their mammoth counterparts. They topped the day-neutral varieties at 18 leaves and allowed the mammoth varieties to produce 22 leaves and removed and discarded four basal leaves. They reported that 'mammoth NC 2326' produced higher yields than normal NC 2326 but 'Mammoth Speight G-28' produced lower yields than any other variety. Total alkaloids and reducing sugars were also lower for the mammoth cultivars than for their respective day-neutral counterparts. However, the higher yielding mammoth produced higher reducing sugar concentrations leaf than the lower yielding mammoth variety.

King (10) investigated the effect of varying topping height of mammoth varieties on yield, quality, and value per hectare. He found that yield, grade index, value per hectare, and reducing sugar-to-alkaloid ratios increased but total alkaloids, reducing sugars, and total nitrogen decreased as topping heights were increased from 14 to 26 leaves.

Collins and Miner (4, 5) investigated the feasibility of not harvesting the lower four leaves on day-neutral tobacco varieties. They found that removing and discarding four basal leaves at layby decreased yield but had little effect on quality index. The authors suggested that removing these leaves may: decrease occurrence of blue mold, decrease interference with harvest activities, and decrease drain on the plant's resources.

The objective of this study was to compare the influence of removing and discarding 0, 4, 6, or 8 basal leaves and topping the plants 0, 4, 6, or 8 leaves higher, respectively, on several agronomic traits and chemical components of NC 27 NF.

Materials and Methods

A field study was conducted at the Southern Piedmont Agricultural Experiment Station near Blackstone, Virginia to determine the effects of basal leaf removal of mammoth varieties of flue-cured tobacco. The experiment was designed as a randomized complete block with four replications. Treatments consisted removing and discarding 0, 4, 6, or 8 leaves from the plants in each plot at topping time. Plants were topped either 0, 4, 6, or 8 leaves higher (0+0, 4+4, 6+6, and 8+8)to give 20 harvestable leaves.

Individual plots consisted of single rows spaced 122 cm apart containing 24 plants spaced 54 cm apart within the row. One plant from each end of each plot was eliminated from the harvest.

Conventionally produced seedlings of the cultivar 'NC 27 NF' were transplanted into raised beds on May 4. Plots were topped and basal leaves were removed and discarded on July 20. Plants were topped at twenty leaves per plant after basal leaf removal and Prime + was applied for sucker control.

Other than basal leaf removal, all practices were in accordance with Virginia Cooperative Extension Service recommendations (8). Harvested tobacco was cured in a conventional flue-cured tobacco barn. Cured leaf from each harvest of each plot was weighed and assigned an official

U.S. government grade by a USDA Marketing Service tobacco inspector and plot yields and grade indices were computed (2). A representative composite sample was obtained for each plot by harvest and analyzed for total alkaloids and reducing sugars (6, 7). Plant height was measured on five competitive plants per plot on September 30. Individual plant measurements were averaged for each plot prior to statistical analysis.

Results and Discussion

Varying the number of basal leaves removed and discarded significantly affected quality indices and percent maturity but not yield, value per hectare, or average price (Table 1). Removing eight basal leaves decreased quality indices and percent maturity below the levels obtained for the other treatments (Table 2). Plants actually produced 28 leaves with the "8+8" treatment, using a great deal more nutrients and photosynthate for production of leaves that were discarded. Loss of nutrients and photosynthate resulted in lower quality indices and lack of maturity of the harvested leaves. These results correspond to those found in the literature (3, 9, 11, 12, 14). With exception of findings by King (10), previous studies reported increased topping height decreased quality indices.

Increasing the number of basal leaves removed and substituting additional top leaves also increased plant height (Table 2). More internodal regions are also produced as more leaves are produced per plant, thereby increasing plant height.

Removing more basal leaves also decreased the percentage of cured leaf grading in the priming (P) group and increased the percentage of cured leaf grading in the cutter (C) group (Table 2). This inverse relationship would by expected since the lower leaves being discarded

Table 1. Statistical significance of basal leaf removal on selected agronomic traits and chemical constituents of 'NC 27 NF,1988.

Factor	Significance
Yield	NS
Value	NS
Index	**
Average price	NS
Leaf maturity	**
Plant height	**
<u>Grade Factors</u>	
Primings	**
Lugs	NS
Cutters	*
Leaf	NS
Smoking leaf	NS
Nondescript	NS
<u>Total alkaloids</u>	
Stalk Position	
A	NS
B	NS
C	NS
D	NS
E	**
<u>Reducing Sugars</u>	
Stalk Position	
A	**
B	**
C	*
D	NS
E	NS
<u>Reducing Sugar/ alkaloid Ratio</u>	
Stalk Position	
A	*
B	**
C	NS
D	NS
E	*

Table 2. Influence of leaf management on yield, quality index, height, leaf maturity, and percentage primings (P), lugs (X), cutters (C), and leaf (B) in 1988.

					Grade factors			
	Yield	Quality index	Height	Maturity	P	X	C	B
Leaf management	kg ha^{-1}		cm	----------	----------	%	----------	----------
0 + 0	3310a*	55.3a	79a	43.0a	13.8a	8.7a	17.8a	58.0a
4 + 4	3277a	50.8ab	92b	29.5a	4.0b	17.0a	23.5ab	53.5a
6 + 6	3353a	44.5ab	93b	12.8b	0.0b	12.8a	32.8bc	53.3a
8 + 8	3257a	42.3c	102c	9.3b	0.0b	4.0a	34.3c	60.5a

*Means in the same column followed by the same letter are not significantly different at the .05 level according to Duncan's new multiple range test.

are those generally grading in the priming category and those produced at the higher leaf positions as replacements should be either in the cutter or leaf category.

Maintaining acceptable cured leaf chemistry is a concern with mammoth varieties. These varieties tend to produce relatively low nicotine and high reducing sugars (3, 9, 11, 12, 14). Reducing sugars were higher, the total alkaloids were lower, and the sugar to alkaloid ratios were higher for some leaf positions when four to eight basal leaves were removed from NC 27 NF (Table 3). In this study, total alkaloids were too low for a desirable smoke regardless of the basal leaf removal treatment (13). On the other hand, reducing sugars and reducing sugar to alkaloid ratios were adequate for a desirable smoke and good flavor (13).

Table 3. Influence of leaf management on total alkaloids, reducing sugars, and reducing sugar-to-alkaloid ratios in 1988.

Leaf management	Stalk Position 1	2	3	4	5
			Total alkaloids		
0+0	1.8a*	2.2a	2.1a	2.1a	2.8a
4+4	1.9a	2.1a	1.8a	2.1a	2.1b
6+6	1.9a	2.1a	2.1a	1.9a	2.0b
8+8	2.1a	2.0a	1.9a	2.0a	1.9b
			Reducing sugars		
0+0	12.5a	15.8a	21.9a	20.9a	17.0a
4+4	16.9b	20.0b	21.8a	20.4a	17.4a
6+6	17.7b	19.5b	21.8a	19.5a	19.1a
8+8	19.6b	21.8b	19.8b	18.9a	16.3a
			Reducing sugar-to-alkaloid ratio		
0+0	7.3a	7.3a	10.4a	10.3a	6.3a
4+4	9.1b	9.7b	12.7a	10.0a	8.4b
6+6	9.7b	9.9b	10.4a	10.4a	9.9b
8+8	9.5b	11.4b	10.6a	9.7a	8.8b

*Means in the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's new multiple range test.

Summary

The number of lower leaves removed from the mammoth variety, 'NC 27 NF', affected several important agronomic factors. Removing more than six leaves decreased quality index, leaf maturity, and total alkaloids below acceptable levels. Removing four to six leaves had no significant effect on quality index or percent maturity compared to no leaf removal. Removing more than four leaves practically eliminated cured leaf grading in the priming (P) group and shifted production toward a higher proportion of X, C, or B grade groups. Adequate reducing sugar levels and reducing sugar to nicotine ratios were obtained from all leaf removal treatments. Removing four to six basal leaves would be beneficial from a quality and marketability standpoint if the total alkaloids could be increased to acceptable levels.

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Chapter IV

Influence of nitrogen rate, harvest frequency, and time and number of basal leaf removal on agronomic traits and chemical constituents of NC 27 NF

Abstract

Concern over decreased labor availability and desire to decrease production of undesirable downstalk tobacco without yield losses has spurred interest in developing a field management system for mammoth cultivars. Field experiments were conducted in 1987 and 1988 at the Southern Piedmont Agricultural Experiment Station near Blackstone, Virginia to determine an adequate field management system for mammoth cultivars of flue-cured tobacco. Individual tests were arranged as randomized complete blocks with a split-split-split plot treatment design and three replications. Main plots consisted of 67 or 94 kg of nitrogen ha^{-1}. Sub-plots consisted of three harvest frequencies (5, 3, or 2 times over). Sub-sub-plots consisted of three basal leaf removal times (two weeks after final cultivation, topping time, and senescence). Sub-sub-sub-plots consisted of three leaf management regimes (4+4, 6+6, and 8+8). Four, six, or eight basal leaves were removed and discarded and plants were topped four, six, or eight leaves higher to provide 20 harvestable

leaves. Increasing nitrogen rate increased values per hectare and total alkaloids in 1987, but not in 1988. More lugs (X) were obtained as the number of harvests increased. Reducing sugars increased for stalk positions A and B, and decreased for stalk position C in 1988, as number of harvests increased. Delayed leaf removal time resulted in increased yields, values per hectare, and total alkaloids but decreased percentage lugs, in 1987. Reducing sugars in stalk position A increased as leaf removal was delayed in 1988. Removing fewer basal leaves increased yields, values per hectare, percentage smoking leaf (H), and alkaloids for stalk position B in 1988 but decreased plant height, percentage leaf (B), and reducing sugars in stalk positions A, B, and D in 1988. Percentage lugs (X) decreased as basal leaf removal was delayed and the number of basal leaves removed was increased from 4 to 8. Percentage cutters (C) increased with delayed basal leaf removal and decreased harvest numbers. Above normal nitrogen rate, 3 or 5 time harvest, and 4 to 6 basal leaves removed at topping or through senescence provided the best field management system for mammoth cultivars in this study.

Introduction

Introduction of the mammoth gene into acceptable genetic backgrounds may provide a major management advancement for flue-cured tobacco production. The mammoth or non-flowering characteristic causes day-neutral plants to flower only under short-day photoperiods, thereby controlling early flowering, synchronizing topping and sucker control treatments, and increasing the possible number of leaves produced during a normal growing season. Flue-cured tobacco from lower stalk positions has increased the Flue-Cured Tobacco Cooperative Stabilization Corporation inventory as demand for downstalk tobacco deteriorated (1, 13). However, planting mammoth cultivars may eliminate downstalk leaves without decreasing yield and quality.

Allowing mammoth cultivars to produce greater leaf numbers per plant increased yields and decreased suckers but reduced alkaloids and quality indices in contrast to day-neutral varieties (15, 16). Wernsman and Matzinger (26) observed that yields increased, alkaloids decreased, and reducing sugars increased when mammoth varieties were allowed to produce higher leaf numbers. Chaplin (6) also noted that quality decreased as leaf numbers increased on 'Hicks Mammoth'. He concluded that the inferior quality of mammoth varieties was not directly related to the mammoth gene.

King (14) investigated the effect of varying topping heights of mammoth varieties on yield, quality, value per hectare, and leaf chemistry. He observed that as topping height increased from 14 to 26 leaves yield, quality index, and value increased but leaf chemistry was poor.

Jones and Terrill (13) compared two day-neutral cultivars with their mammoth counterparts. The day-neutral plants were topped at 18 leaves and the mammoth plants were topped at 22 leaves with the bottom four leaves removed and discarded. They observed that 'mammoth NC 2326' produced higher yields than normal 'NC 2326'. 'Mammoth Speight G-28' produced lower yields than the day-neutral counterpart. Total alkaloids and reducing sugars were lower for the mammoths than for their day-neutral counterparts. However, 'mammoth NC 2326' produced higher reducing sugar levels than 'mammoth Speight G-28'.

Nitrogen availability plays a key role in tobacco growth and development (21). Several researchers have investigated the influence of nitrogen fertilization on many day-neutral flue-cured tobacco varieties (5, 7, 18, 19, 24). Generally, they observed that increasing nitrogen rates above the normal recommendation gave little or no increase in yield or nicotine, decreased reducing sugars, and altered the quality index. In fact, nitrogen rates equal to or less than the normal recommendation should be used for optimum yield, quality, value, and leaf chemistry.

Increased labor costs and decreased labor availability for tobacco harvesting in recent years stimulated interest in reducing harvest numbers (3, 9, 10). However, decreasing the number of harvests also caused concern over the ripeness of tobacco and the subsequent suitability of the cured leaf for manufacture of smoking products. Ripe tobacco reportedly cures easier, responds better to aging, and provides a more flavorful, palatable smoke (20).

Several researchers have varied harvest rates and studied the influence on yield, quality, value, and leaf chemistry (3, 4, 9, 10, 18, 19, 20, 23, 25). Generally, they found that yields decreased, quality decreased, reducing sugars decreased, and total alkaloids increased as the number of harvests decreased . Higher yields, quality indices, and reducing sugars were observed as harvests were delayed until the leaves reached ripeness.

The objective of this study was to develop a management system for mammoth varieties of flue-cured tobacco which optimizes agronomic traits and chemical constituents of the cured leaf by varing nitrogen rates, harvest numbers, and times and numbers of lower leaf management.

Materials and Methods

Field experiments were conducted in 1987 and 1988 at the Southern Piedmont Agricultural Experiment Station near Blackstone, Virginia on a Durham sandy loam soil (Typic Hapludult, fine-loamy, siliceous, thermic). Experiments were designed as a randomized complete block with a split-split-split plot arrangement and three replications.

Main plots consisted of two nitrogen rates: 67 kg ha^{-1} (the suggested rate based on soil characteristics) and 94 kg ha^{-1} (40% above the suggested rate). Sub-plots consisted of harvesting plots in 4 leaf increments a total of 5 times, harvesting plots 3 times by removing 6 leaves in the first harvest and 7 leaves in the subsequent harvests, and harvesting plots twice by removing 10 leaves at each harvest. Sub-sub-plots consisted of removing basal leaves two weeks after final cultivation, topping time, or senescence / burn-off. Sub-sub-sub-plots consisted of removing and discarding 4, 6, or 8 basal leaves from each plant at one of the three specified times and topping 4, 6, or 8 leaves higher (4+4, 6+6, 8+8) respectively, to provide 20 harvestable leaves per plant.

Sub-sub-sub-plots consisted of single rows spaced 122 cm apart containing 24 plants spaced 51 cm apart within the row. A border plant from each end of each plot was eliminated from the harvest.

Conventionally produced seedlings of the cultivar 'NC 27

NF' were transplanted into raised beds on May 7 and May 5, respectively, in 1987 and 1988. Each plot received the equivalent of 67 kg ha^{-1} of nitrogen applied before transplanting. Plots receiving the equivalent of 94 kg ha^{-1} of nitrogen obtained an additional 27 kg nitrogen ha^{-1} using a 16-0-0 fertilizer side-dressed on June 9 and May 19 in 1987 and 1988, respectively.

Layby leaf removal was conducted on June 24 in 1987 and June 29 in 1988. Topping time leaf removal was conducted on July 22 in 1987 and July 25 in 1988. All plants in each plot were topped with 20 harvestable leaves per plant on July 22 and July 25 in 1987 and 1988, respectively. Plants with leaf senescence treatments were topped at 24, 26, or 28 leaves corresponding to a 4+4, 6+6 or 8+8 leaf management regime.

Plants in each plot were examined twice weekly to determine when to harvest. Plots harvested five or three times were harvested when all the leaves to be removed with one pass were deemed ripe. Plots harvested twice were harvested when the six middle leaves to be removed with one pass were deemed ripe. Ripe was based on judgement of leaf development and the cured product that would result. Harvesting began on August 12 and August 1 and was completed on September 29 and September 15 in 1987 and 1988, respectively.

Other than nitrogen application, harvest frequencies, and basal leaf removal all practices were in accordance with Virginia Cooperative Extension Service recommendations (12). Tobacco was cured in a conventional flue-cured barn. Cured leaf of each plot was weighed by harvest, assigned an official U.S. government grade by a USDA Marketing Service tobacco inspector, and plot yields and grade indices were computed (2). A representative, whole-plant sample of cured leaf was obtained for each plot in 1987 and a composite sample by harvest was obtained for each plot in 1988 and analyzed for total alkaloids and reducing sugars (8, 11). Plant height and uppermost leaf length and width were measured on five competitive plants per plot on July 15. 1987. However, only plant height was measured on five plants and averaged for each plot on September 30, 1988.

Results and Discussion

Year by treatment interactions were not found for either year of the study so the data from each year were combined for analysis of variance (17). However, nicotine and reducing sugars could not be combined over years because of difference in sampling techniques between 1987 and 1988. Analyses were conducted on composite whole-plant samples in 1987 and on samples taken by leaf position in 1988.

Agronomic Factors

Yield was not influenced by nitrogen rates or by harvest frequency. However, yields were higher with delayed basal leaf removal and when fewer basal leaves were removed and discarded (Table 4). Decreased yield from removal of basal leaves two weeks after layby probably resulted from reduced leaf area index and photosynthate production during a time of rapid plant growth. Removal of basal leaves at topping time or through senescence should have had little effect on plant growth, photosynthate production, or yield because the plants had reached their full growth potential and were beginning to mature and ripen.

Plants in the 8+8 treatment produced 28 leaves when eight leaves were removed and discarded versus producing 24 or 26 leaves when four or six leaves were removed. Plants producing 28 leaves required more nutrients and photosynthate than plants producing 24 or 26 leaves in order to produce comparable yields. However, in this study

Table 4. Influence of leaf removal time and leaf management on yield, value, quality index, height, leaf maturity, and percentage of primings (P), lugs (X), cutters (C), leaf (B), and smoking leaf (H) factors, 1987 and 1988.

	Yield	Value	Quality index	Height	Maturity	Grade Factors P	X	C	B	H
Leaf Removal	kg ha^{-1}	$/$ha^{-1}$		cm	%					
Layby	3316a*	11811a	55.2a	94a	53.6a	1.3a	29.1a	12.3a	50.7a	3.8a
Topping	3433b	12306b	55.1a	107b	51.7a	0.5a	25.6b	15.4b	54.8b	2.2a
Senesce	3457b	12306b	54.2a	110c	53.3a	0.0a	25.0b	15.9b	52.5ab	3.8a
Leaf Management										
4 + 4	3452a	12324a	56.4a	99a	56.3a	1.0a	28.7a	12.8a	49.9a	4.9a
6 + 6	3421a	12214a	55.1ab	104b	53.5a	0.6a	26.5ab	15.2a	52.9b	2.8b
8 + 8	3337b	11891b	53.1b	108c	48.9b	0.2a	24.5b	15.7a	52.3b	2.1b

*Means in the same column followed by the same letter are not significantly different at the .05 level according to Duncan's new multiple range test.

study all the plants received essentially the same resources, and yields were subsequently lower with the "8+8" leaf management regime.

Percent maturity decreased as more basal leaves were removed. Again the dilution or loss of plant available resources required to produce the desired maturity characteristics created this decline in maturity.

Values per hectare increased with increased nitrogen rate, later basal leaf removal, and fewer basal leaves removed (Tables 4 and 5). Increased values per hectare at the higher nitrogen rate (94 kg ha^{-1}) is not easily explained because no corresponding increase in yield, quality index, or maturity occurred. On the other hand, increased values per hectare from delaying basal leaf removal until topping or senescence may be explained by the correlating increased yields. Removing four or six basal leaves also increased yield and quality index which caused an increase in value per hectare.

Plant height increased when basal leaf removal was delayed until topping or senescence. Plant height also increased as more basal leaves were removed and the overall number of leaves produced per plant increased from 24 to 28. (Table 4).

Table 5. Influence of nitrogen rate on yield, value per ha, and quality index, 1987 and 1988.

Nitrogen ($kg\ ha^{-1}$)	Yield ($kg\ ha^{-1}$)	Value ($/ha)	Quality Index
67	3158a*	11600a	56.8a
94	2918a	12673b	52.9a

*Means in the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's new multiple range test.

Leaf grades

Primings were only produced with a five-time harvest, and only 1.5 percentage of the cured leaf graded in the priming category then. This decrease in the percentage of primings wolud be expected since the basal leaves being discarded were those normally grading in the priming category. When a three time or two time harvest was employed, a great deal of mixing of stalk positions occurred and, therefore, very little of the cured leaf graded in the priming grade.

Decreases in the percentage of primings shifted production toward increased proportions of upper leaf grades. The percentage of cured leaf grading in the lug (X) group was significantly influenced by harvest frequency, leaf removal time, and an interaction between leaf removal time and leaf management regime. More lugs were produced with a three time or five time harvest (Table 6). The percentage of cured leaf in the lug category decreased as more basal leaves were removed and as removal of basal leaves was delayed (Fig. 1), except with the 4+4, layby treatment. The smallest percentage of lugs was produced with 8+8, senescence treatments.

Later removal dates and fewer harvests generally produced a higher percentage of cutters (Fig. 2). Two-time harvest produced the highest percentage of cutters for both the senescence and layby treatments. Layby removal times

Table 6. Influence of harvest frequency on proportion of total cured leaf assigned to official U.S. government grade leaf groups, 1987 and 1988.

Harvest Frequency	Primings (P)	Lugs (X)	Cutters (C)	Leaf (B)	Smoking Leaf (H)
Number	%				
5	1.5a	27.5ab	13.9a	50.4a	4.8a
3	0.2b	29.4a	12.6a	52.0a	2.2a
2	0.0b	22.9b	17.1a	55.6a	2.7a

Numbers in the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's new multiple range test.

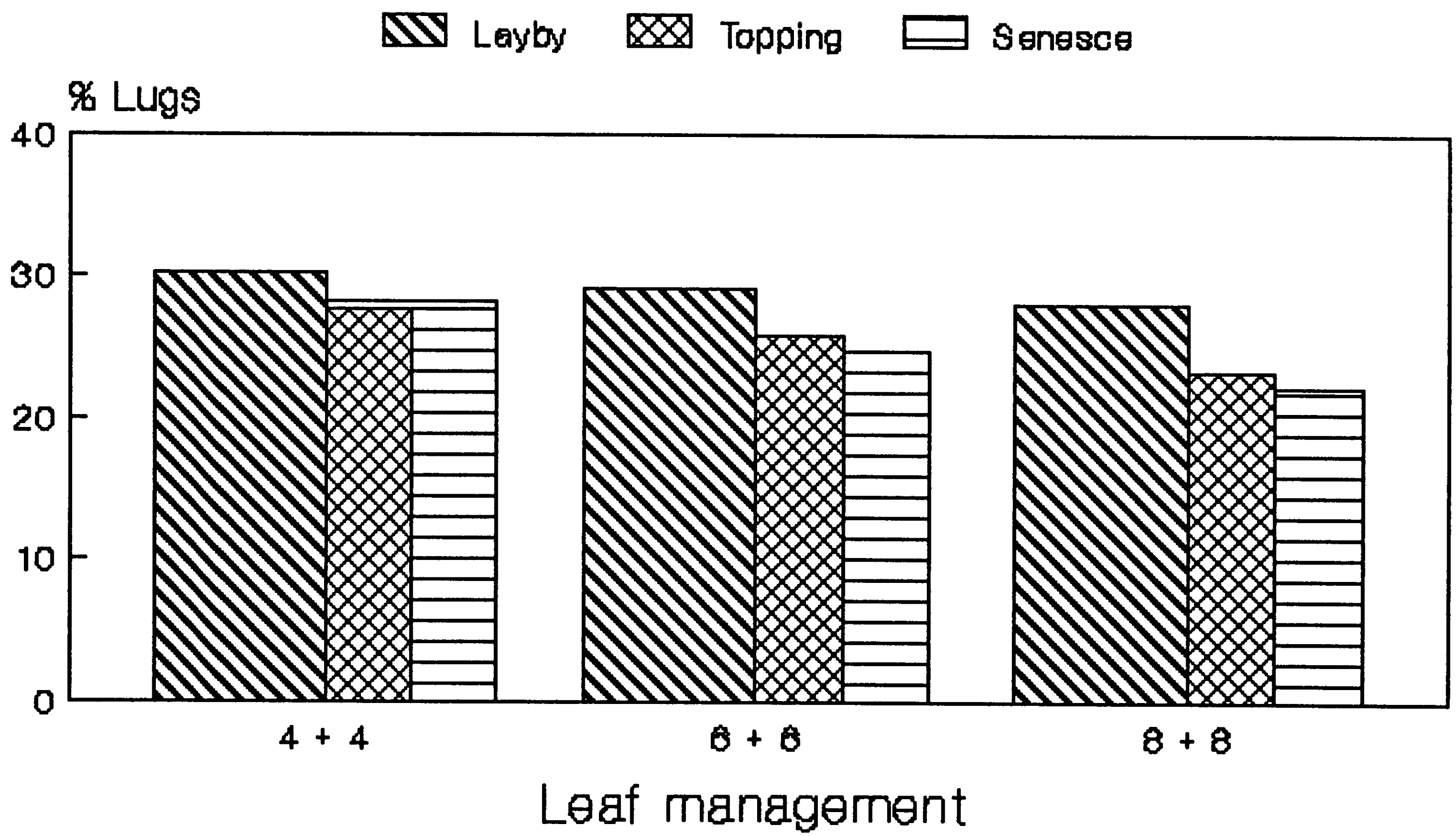

Figure 1. Influence of leaf management by leaf removal on percentage lugs in 1987.

and a three-time harvest produced the lowest percentage of cutters. With senescence leaf removal the least cutters were found with a five-time harvest. When basal leaves were removed at topping time no differences in percentage cutters were observed between harvets frequencies (Fig. 2).

Percentage of leaf increased and percentage of smoking leaf decreased as more basal leaves were removed (Table 4). No smoking leaf was produced with a "4+4" leaf management regime and very little smoking leaf was produced with the other management regimes at the 67 kg ha^{-1} nitrogen rate (Fig. 3). However, at the 94 kg ha^{-1} nitrogen rate the most smoking leaf was produced with the "4+4" leaf management regime.

Leaf Chemistry

Increasing nitrogen rate increased total alkaloids (Table 7) in 1987 but did not affect reducing sugars. A similar increase in total alkaloids was observed in 1988 for stalk positions A and D (Table 8). Early basal leaf removal increased alkaloids in 1987 (Table 7). Similar results also were noted in 1988 for stalk positions A and B (Table 8). These results were unexpected since the greatest alkaloid accumulation generally takes place after topping time. However, some alkaloids accumulate prior to topping and may have been responsible for the observed difference (22).

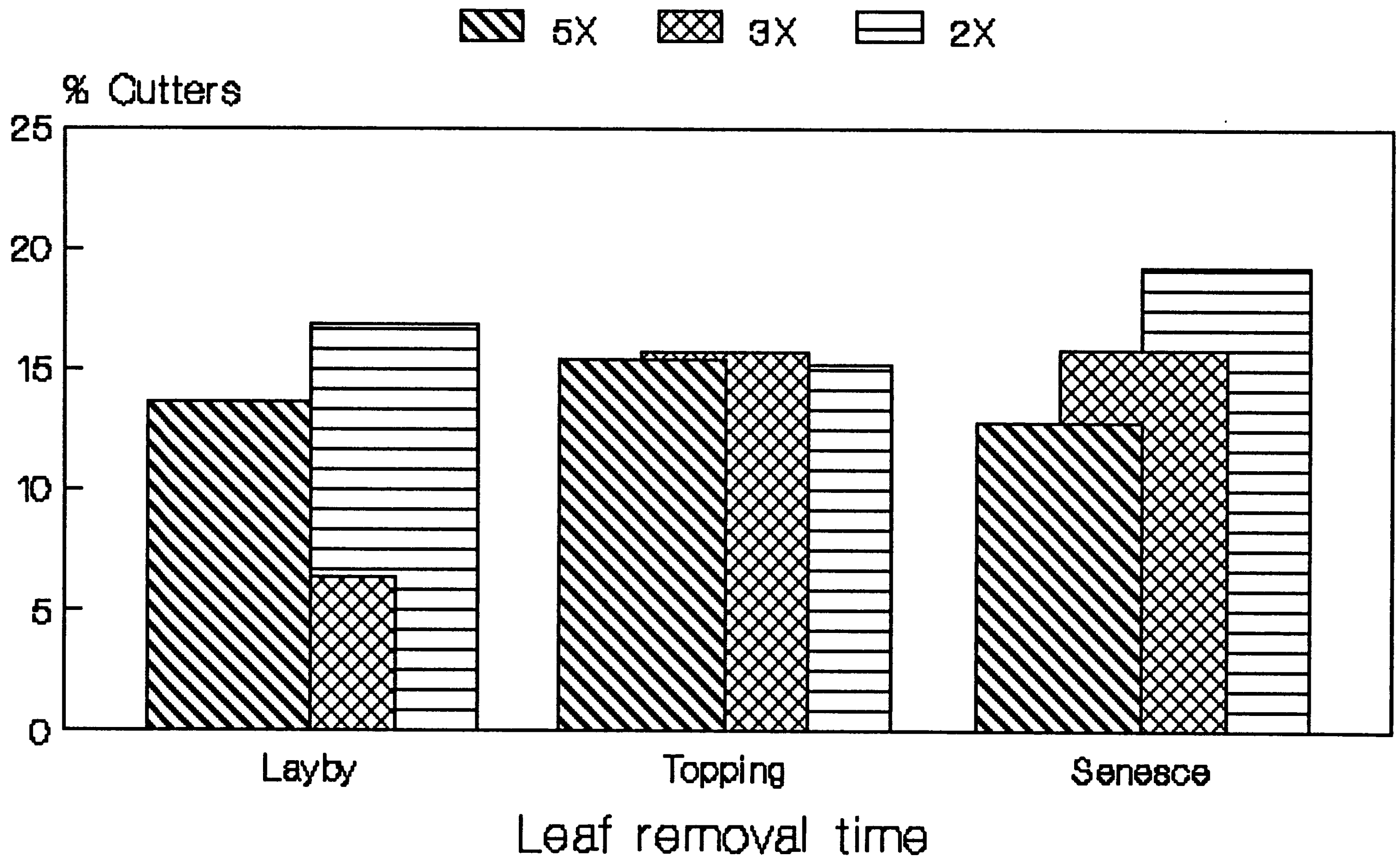

Figure 2. Influence of leaf removal time by harvest on percentage cutters in 1987.

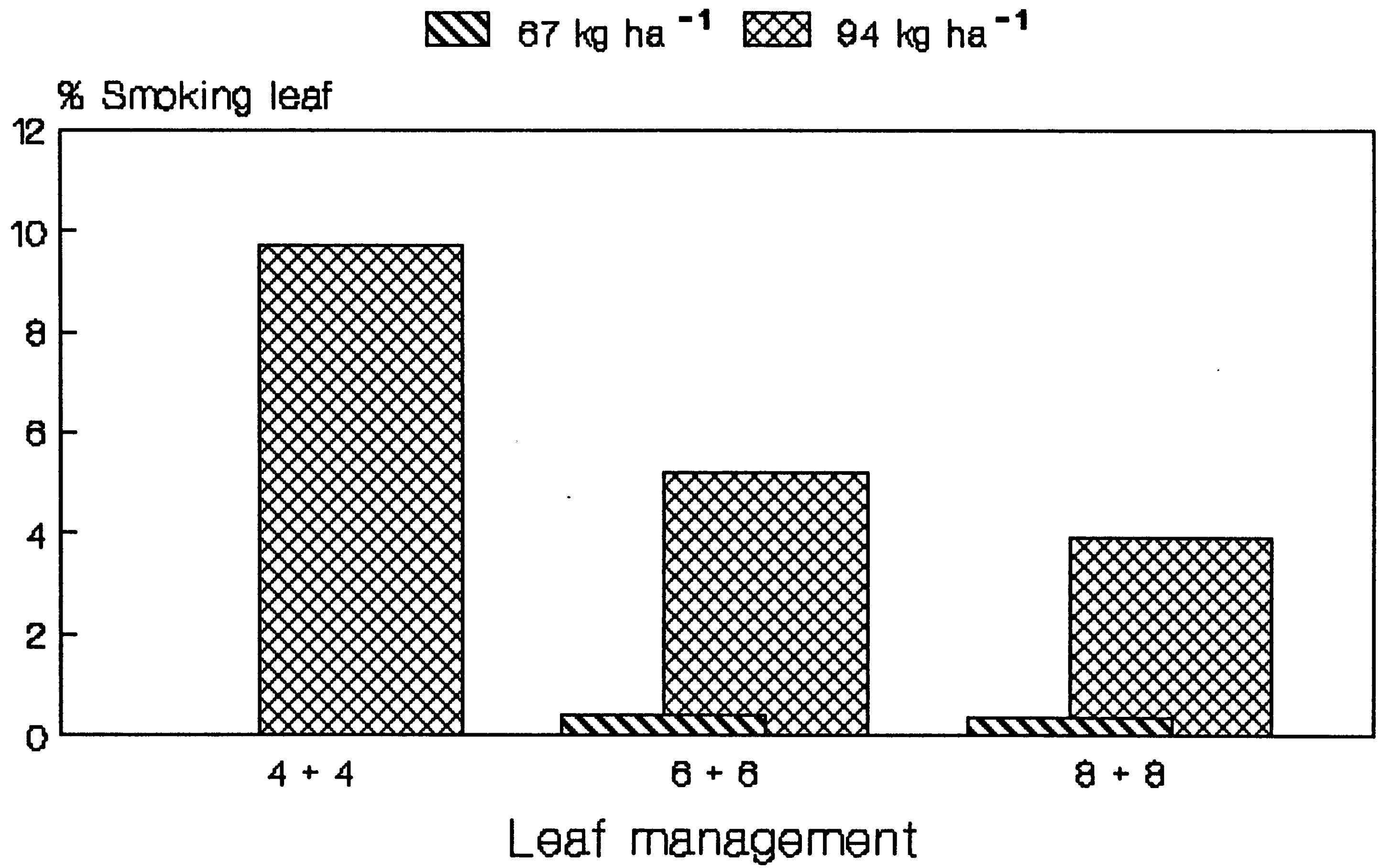

Figure 3. Influence of leaf management by nitrogen rate on percentage smoking leaf in 1988.

Table 7. Influence of nitrogen rate and leaf removal time on total alkaloids and reducing sugars, 1987.

Treatment	Total alkaloids	Reducing sugars
Nitrogen rate	---------%----------	
67 kg ha^{-1}	2.0a*	27.3a
94 kg ha^{-1}	2.5b	25.4a
Leaf removal time		
	---------%----------	
Layby	2.7a	25.4a
Topping	2.2b	26.4b
Senesce	2.0c	27.3c

*Means in the same column with the same letter are not significantly different at the 0.05 level according to Duncan's new multiple range test.

Table 8. Influence of nitrogen rate and leaf removal time on total alkaloids and reducing sugars by stalk position in 1988.

Treatment	Stalk Position A	B	C	D	E
Nitrogen rate kg ha^{-1}	%				
	Total alkaloids				
67	1.9a*	1.7a	1.7a	2.0a	1.9a
94	2.3b	2.2a	2.3a	1.7b	2.4a
	Reducing sugars				
67	18.8a	20.0a	20.2a	19.6a	19.1a
94	13.4a	18.3a	18.9a	19.2a	18.4a
Leaf removal	%				
	Total alkaloids				
Layby	2.4a	2.1a	2.1a	1.9a	2.0a
Topping	2.0b	1.9b	2.0a	1.9a	2.2a
Senesce	1.9b	1.9b	2.0a	1.9a	2.2a
	Reducing sugars				
Layby	14.5a	18.7a	19.1a	18.2a	18.7a
Topping	17.2b	19.5a	20.1b	19.9ab	18.9a
Senesce	16.5b	19.3a	19.5ab	20.2b	18.6a

*Means in the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's new multiple range test.

Total alkaloids were also influenced by leaf management regimes for stalk position B in 1988 (Table 9). Generally, the total alkaloids decreased as more leaves were removed. This observation corresponds to the results from other leaf managment studies indicating that as topping height increased, reducing sugar levels decreased (6, 13, 15, 16, 26).

Total alkaloid levels were not adequate enough to produce a flavorful, palatable smoke according to Tso's criteria (22). In fact, these alkaloid levels should provide a mild, irritable smoke which lacks flavor. Only when basal leaves were removed at layby did alkaloid levels reach a level even close to the desired levels.

Delaying basal leaf removal significantly increased reducing sugars in 1987 (Table 7). However, all reducing sugar levels were adequate in 1987 for desirable quality and smoke (22). Delaying leaf removal increased reducing sugars at stalk position A, C, and D in 1988 (Table 8).

Increased numbers of basal leaves removed also increased reducing sugars at stalk positions A. (Tables 9). However, these effects were not evident at other stalk positions.

Harvest frequency influenced reducing sugars at stalk positions A, B, and C in 1988 (Table 9). As more harvests were employed, reducing sugars increased for leaves removed

Table 9. Influence of leaf management and harvest frequency on total alkaloids and reducing sugars by stalk position in 1988.

Treatment	Stalk Position A	B	C	D	E
Leaf Management			%		
			Total alkaloids		
4+4	2.1a*	2.0a	2.1a	1.8a	2.2a
6+6	2.1a	2.0ab	2.0a	1.9a	2.0a
8+8	2.1a	1.9b	2.0a	1.9a	2.2a
			Reducing sugars		
4+4	14.9a	18.9a	19.6a	20.1a	18.9a
6+6	15.5a	19.4a	20.0a	19.0a	19.2a
8+8	17.9b	19.3a	19.2a	19.1a	18.1a
Harvest Number			%		
			Total alkaloids		
5	2.1a	2.0a	1.9a	1.9	2.1
3	2.2a	2.0a	1.9a	---	---
2	2.1a	1.9a	---	---	---
			Reducing Sugars		
5	14.8a	18.0a	20.2a	19.4	18.7
3	15.4a	20.4b	18.9b	----	----
2	18.0b	19.1c	-----	----	----

*Means in the same column followed by the same letter are not significantly different at the 0.05 level according to Duncan's new multiple range test.

during the second harvest and decreased for leaves removed during the third harvest. There is no obvious explanation for this result.

Summary

Yield, value per hectare, quality index, and leaf maturity were greatest when four or six leaves were removed at topping or allowed to senesce and burn-off the stalk. Value per hectare was also greatest at the high nitrogen rate (94 kg ha^{-1}).

Less cured leaf graded in the priming (P) and lug (X) groups and more in the cutter (C) and leaf (B) groups when plots were harvested less frequently, basal leaf removal was delayed, and more basal leaves were removed and discarded. In fact, very little leaf graded in the priming or lug category, regardless of when the leaves were removed or how many basal leaves were removed. Any basal leaf removal at any time during the growing season may greatly reduce the proportion of primings and lugs.

Total alkaloids increased with 94 versus 67 kg nitrogen ha^{-1} and when basal leaves were removed early, and when only four basal leaves were removed and discarded. Reducing sugars were greater when the basal leaves were removed at topping or allowed to senesce. However, reducing sugars from all treatments were adequate for a desirable smoke (22).

Results indicate that the best management system for 'NC 27 NF' includes above normal nitrogen rates, a three time or five time harvest, and four to six basal leaves removed at topping time or through senescence. However,

the total alkaloids in the cured leaf need to be increased to desirable levels without significantly altering the other parameters measured. Additional research is warranted to evaluate the possibility of removing the basal leaves sometime between layby and topping.

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Chapter V

Influence of chemical topping with flumetralin (Prime+), fatty alcohol, and maleic hydrazide alone and in various combinations on agronomic and chemical properties of NC 22 NF and NC 27 NF

Abstract

Mammoth cultivars do not flower under normal growing conditions and produce uniform growth and flower production thus lending themselves to the possibility of chemical topping. Field experiments were conducted at the Southern Piedmont Agricultural Experiment Station near Blackstone, Virginia in 1987 and 1988 to determine the influence of chemical topping on several agronomic and chemical factors of NC 22 NF and NC 27 NF. The experiments were designed as randomized complete blocks with a split-plot arrangement and four replications. Main plots consisted of two non-flowering varieties,'NC 27 NF' and 'NC 22 NF'. Sub-plots consisted of four topping treatments in 1987: a hand topped check with fatty alcohol (FA) and maleic hydrazide (MH) applied for sucker control, chemical topping with a FA / MH sequential application, chemical topping with MH, and chemical topping with flumetralin (Prime+). Three topping treatments were added in 1988: a topped not suckered

control, chemical topping with a flumetralin - FA tank mix, and chemical topping with a split application of MH. Compared to hand-topping, chemical topping resulted in taller plants with more leaves, narrower top leaves, lower total alkaloids, and equal or higher reducing sugars. Chemical topping also produced longer top leaves than hand topping in 1987. The flumetralin - FA tank mix was the only treatment in 1987 which did not produce leaf length, leaf width, and leaf number significantly different from the hand-topped check. MH treatments produced lower yields and values per hectarre than the hand-topped control but had more suckers than all other treatments. The FA / MH treatment resulted in higher yields and lower grade indices than the hand topped control. NC 22 NF was taller, produced higher yields and values per hectare, more suckers, and a higher percentage of reducing sugars than NC 27 NF. NC 22 NF had longer tip leaves than NC 27 NF except when topped chemically with maleic hydrazide. Chemical topping with flumetralin or FA / MH or a flumetralin - FA tank mix provided comparable yields, values, quality indices, and reducing sugars to hand topping.

Introduction

Mammoth varieties are photoperiod sensitive varieties of flue-cured tobacco which flower only during short day lengths. These varieties grow season long in the tobacco producing regions of the southeastern United States without loosing apical dominance and flowering. Mammoth cultivars practically eliminate premature floral emergence and increase synchronization of topping and sucker control efforts (11). Due to the uniform growth and delayed flowering of mammoth cultivars, chemical topping may become a means of topping and controlling suckers.

Chemical topping is not a currently recommended or used practice for flue-cured tobacco production (6). However, a limited amount of preliminary work has been performed to evaluate the effectiveness of chemical topping. Flue-cured tobacco should be topped when 18 to 20 harvestable leaves have developed. These leaves are generally produced by the prebutton stage facilitating early topping, possibly chemical topping. The floral parts of a tobacco plant drain the plant of nutrients and photosynthate necessary for leaf development and, therefore, decrease crop yields and quality. However, yield and quality levels may be significantly increased if day-neutral tobacco plants are chemically topped prior to flower formation (6).

Steffens and Mckee (9) conducted chemical topping experiments using a fatty alcohol (1-Decanol) on 'Maryland

64' in 1967. The fatty alcohol provided excellent control of flowering and sucker production if the chemical was applied during the button stage. Steffens and Mckee also noted that chemically topped tobacco produced yields, values per hectare, and leaf chemistry equal to or greater than those produced by conventionally topped tobacco.

Coulson (3) compared maleic hydrazide as a topping and sucker control agent on both topped and non-topped plants with hand-topping and suckering. Failing to hand top day-neutral plants reduced alkaloids and increased sugar-to-alkaloid ratios but had no significant effects on reducing sugars. A similar study by DeBaets (5) showed that not topping day-neutral flue-cured tobacco varieteis decreases nicotine levels in wrappers and tips by 50% or more. Alkaloid levels were lower and sugar-to-alkaloid ratios were slightly higher than the levels for any other treatments when maleic hydrazide was used for chemical topping and sucker control.

The objectives of this study were:

1) to determine the feasibility of chemical topping two mammoth or non-flowering varieties of flue-cured tobacco (NC 22 NF and NC 27 NF),

2) to determine the efficacy of flumetralin, fatty alcohol, and maleic hydrazide for chemical topping, both alone and in various combinations.

Materials and Methods

Field experiments were conducted at the Southern Piedmont Agricultural Experiment Station near Blackstone, Virginia in 1987 and 1988. Experiments were designed as a randomized complete block with a split-plot arrangement and four replications. Main plots consisted of two non-flowering varieties,'NC 27 NF' [(C 319 x NCTG21) x C 319] and 'NC 22 NF' [(SC 58 x NC 2326) x NC 2326]. Sub-plots consisted of four topping treatments in 1987: a hand-topped control with fatty alcohol and maleic hydrazide applied for sucker control, chemical topping with a fatty alcohol / maleic hydrazide sequential application, chemical topping with maleic hydrazide, and chemical topping with flumetralin (Prime+). These treatments were used in 1988 with the addition of three other topping treatments: a topped-not-suckered control, chemical topping with a flumetralin and fatty alcohol tank mix, and chemical topping with a split application of maleic hydrazide.

Sub-plots consisted of single rows spaced 122 cm apart containing 24 plants spaced 51 cm apart within the row. A single plant from each end of each plot was eliminated from the harvest and four basal leaves were removed from each plant of each plot and discarded.

Conventionally produced plants were transplanted into raised beds on May 6 and May 2 in 1987 and 1988, respectively. Chemical topping treatments were applied when the plants reached the 18 to 20 leaf stage. Twenty-five milliliters per plant of each spray solution was applied using a CO_2 pressurized back-pack sprayer equipped with a single full cone nozzle (Tee Jet TG-3) at a pressure of 173 kPa. All the chemicals were applied at the manufacturer's recommended rate: fatty alcohol at 5% (Off-Shoot-T at 9.3 kg ha^{-1}), Prime + at 2% (3.7 kg ha^{-1}), maleic hydrazide (Royal MH-30 at 2.7 kg ha^{-1}), and the split maleic hydrazide (Royal MH-30 at 1.4 kg ha^{-1}).

Other than chemical topping and basal leaf removal, all other practices were in accordance with the Virginia Cooperative Extension Service recommendations (8). Plants in each plot were harvested five times in both 1987 and 1988. Tobacco was cured in a conventional flue-cured tobacco barn. Cured leaf from each harvest of each plot was weighed by harvest, assigned an official U.S. government grade from a USDA Marketing Service tobacco inspector, and plot yields and grade indices were computed (2). A representative whole-plant sample of cured leaf was obtained for each plot in 1987 and a composite sample, by harvest, was obtained for each plot in 1988 and analyzed for total alkaloids and reducing sugars (4, 7).

Plant height, uppermost leaf length and width, and leaf number were obtained on five competitive plants of each plot on July 8, 1987. However, only plant height and leaf number were measured on five plants on August 22, 1988.

Sucker control was expressed as number of suckers per plant and weight of suckers per plant by averaging the number and weight of suckers harvested from five competitive plants of each plot. Prcent sucker control was expressed in 1988 as percent reduction in the ratio of green weight of suckers from treated plants and the green weight of suckers from plants which were topped but not suckered.

Results and Discussion

Plant Measurements.

Chemical topping and sucker control treatment significantly influenced plant height, leaf length, leaf width and leaf number. Chemically topped plants were taller and had a greater number of leaves and shorter, narrower tip leaves than the hand-topped treatment in 1987 (Table 11). The flumetralin treatment also produced significantly wider leaves than maleic hydrazide treated plants. Chemical topping treatments again produced taller plants with a greater number of narrower top leaves than the hand-topped treatment in 1988, with one exception: the flumetralin - fatty alcohol tank-mix (Table 12). The flumetralin - fatty alcohol tank mix produced plants with similar leaf number and tip leaf length and width to the hand-topped control. Only the fatty alcohol-maleic hydrazide sequential treatment produced shorter top leaves than the hand-topped check in 1988.

Varietal differences were also detected in plant height in both 1987 and 1988. NC 22 NF produced taller plants than NC 27 NF regardless of topping treatment (Table 13). NC 22 NF grows faster than NC 27 NF. When both varieties were topped at the same time, NC 22 NF had grown taller than NC 27 NF.

Table 10. Significance of chemical topping treatments from analysis of variance, 1987 and 1988.

Character	Variety		Treatment		V x T	
	1987	1988	1987	1988	1987	1988
% sucker control	--	NS	--	**	--	**
No. suckers/plant	*	NS	**	**	NS	NS
Wt. suckers/plant	NS	**	**	**	NS	**
Plant height	**	**	**	**	NS	NS
Leaf length	NS	NS	**	**	NS	NS
Leaf width	NS	NS	**	*	NS	NS
Leaf number	NS	NS	**	**	NS	NS
Yield	**	**	**	**	NS	NS
Value	**	*	**	**	NS	NS
Average price	NS	NS	**	**	NS	NS
Grade index	NS	**	**	**	NS	NS
% Reducing sugars	NS	*	**	**	NS	NS
% Nicotine	NS	NS	**	**	NS	NS

* = significant at the 0.05 level, ** = significant at the 0.01 level, and NS = not significant at the 0.05 level according to the Analysis of Variance procedure.

Table 11. Mean agronomic performance, chemical composition, and sucker control efficacy of chemically topped mammoth cultivars in 1987.

Topping trt.	Yield	Value	Quality index	Plant height	Leaf length	Leaf width	Leaf no.	Total alkaloids	Reducing sugars	Suckers	Sucker weight
	kg/ha	$/ha		---------cm---------				---------%---------		no./plant	g/plant
Hand	3371b*	13360b	54.4b	91a	60c	25d	20a	3.00b	23.0a	0.2a	5a
KMH	2942a	10963a	68.4c	114b	52a	19a	24b	2.09a	23.0a	9.1b	558b
Prime +	3620b	13288b	58.3b	115b	54b	21c	25b	2.07a	26.6b	0.9a	43a
FA/KMH	3752c	13373b	47.1a	123b	51a	20b	25b	2.22a	25.3b	0.3a	6a

*Means in the same column followed by the same letter are not significantly different at the .05 level according to Duncan's new multiple range test.

Table 12. Mean agronomic performance, chemical composition, and sucker control efficacy of chemically topped mammoth cultivars in 1988.

Topping trt.	Yield	Value	Quality index	Plant height	Leaf length	Leaf width	Leaf no.	Total alkaloids	Red. sugars	Sucker control	Suckers	Sucker weight
	kg/ha	$/ha		---------cm--------				-------------%------------			no./plt	g/plt
Hand	3396cd*	6943a	59.0a	85a	62b	28b	20a	2.70b	18.2b	99d	0.1a	3a
KMH	2697b	12336c	60.5a	109b	59a	24a	22ab	2.19a	16.1a	41b	10.7d	132b
KMH/KMH	2839b	9798b	61.5a	111b	60ab	23a	23b	2.25a	18.3b	81c	6.8c	36a
Prime+	3236c	10445b	57.6a	105b	58a	24a	22ab	2.18a	18.0b	99d	0.3a	21a
Prime+ + FA	3335c	11878c	56.4a	103b	62b	26ab	21a	2.25a	19.5bc	100d	0.0a	0a
FA/KMH	3460d	12336c	55.0a	110b	57a	24a	23b	2.23a	20.4c	100d	0.0a	0a
TNS	2036a	12714c	60.6a	89a	57a	25a	20a	2.33a	15.1a	0a	4.1b	109b

*Means in the same column followed by the same letter are not significantly different at the .05 level according to Duncan's new multiple range test.

Table 13. Mean agronomic performance, chemical composition, and sucker control efficacy of two mammoth cultivars averaged over chemical topping treatments in 1987 and 1988.

Variety	Yield	Value	Quality index	Plant height	Leaf length	Leaf width	Leaf no.	Total alkaloids	Red. sugars	Sucker control	Suckers	Sucker weight
	kg/ha	$/ha		----------	cm	--------		------------	%	------------	no./plt	g/plt
						1987						
NC 22 NF	3669b*	12714a	56.6a	123b	54.7a	21.2a	23.6a	2.50a	23.8a	--	15b	799a
NC 27 NF	3173a	11610b	57.4a	97a	53.6a	21.3a	22.6a	2.19a	25.1a	--	12a	734a
						1988						
NC 22 NF	3145b	11312a	54.0a	113b	58.3a	24.5a	21.8a	2.50b	17.4a	76a	3.1a	352b
NC 27 NF	2855a	10531b	63.4b	90a	60.6a	25.1a	21.2a	2.11a	18.5a	74a	3.1a	288a

*Means in the same column followed by the same letter are not significantly different at the .05 level according to Duncan's new multiple range test.

Agronomic Factors

Significant differences among topping treatments were obtained for yield, value per hectare, and grade index in both 1987 and 1988 (Tables 10-12). Maleic hydrazide treatments resulted in lower yields, lower values and higher grade indices than the hand-topped control in 1987 and 1988 (Tables 11 and 12). The decreased yields correspond with lack of sucker control from these treatments. As more sucker growth accumulates, less nutrients are used for leaf production and there is a decrease in yields which causes subsequent decreases in values per hectare.

The fatty alcohol / maleic hydrazide treatment produced higher yields and lower grade indices in 1987 than the hand-topped control. These results correspond to those of Steffens and McKee (15). They also found that fatty alcohol treatments provide excellent control of flowering and sucker growth and, therefore, produce equal or higher yields relative to hand topping. Our data indicate that chemical topping with fatty alcohol / maleic hydrazide should provide above-normal yields while chemical topping with maleic hydrazide alone would provide substandard yields and values per hectare regardless of the increased grade indices obtained.

Varietal differences for yield and value were detected in 1987 and 1988 (Table 13). NC 22 NF yielded higher and produced a higher value per hectare than NC 27 NF in both years. NC 22 NF had slightly lower quality indices than NC 27 NF in 1988.

Sucker Control

Sucker control was excellent for all the treatments, except the maleic hydrazide treatment in 1987 and 1988 and the split maleic hydrazide treatment in 1988 (Tables 11 and 12). All three maleic hydrazide treatments averaged greater than 6 suckers per plant while the other chemical topping treatments produced less than one sucker per plant. NC 22 NF produced more suckers per plant than NC 27 NF in 1987, but not in 1988 (Table 13). NC 22 NF also produced a greater total sucker weight than NC 27 NF in 1988. A similar trend in 1987 was not significant. These observations suggest that NC 22 NF produced a greater bulk of axillary bud growth than NC 27 NF by either producing more suckers per plant or heavier suckers per plant. Little difference was noted between varieties except when treated only with maleic hydrazide (Fig 4 and 5). NC 22 NF had a lower percentage of sucker control and therefore, a higher weight of suckers per plant than NC 27 NF. Again, as shown in Tables 11 and 12, all treatments except the three maleic hydrazide treatments provided excellent sucker control regardless of variety.

Leaf Chemistry

One of the most perplexing effects of chemical topping

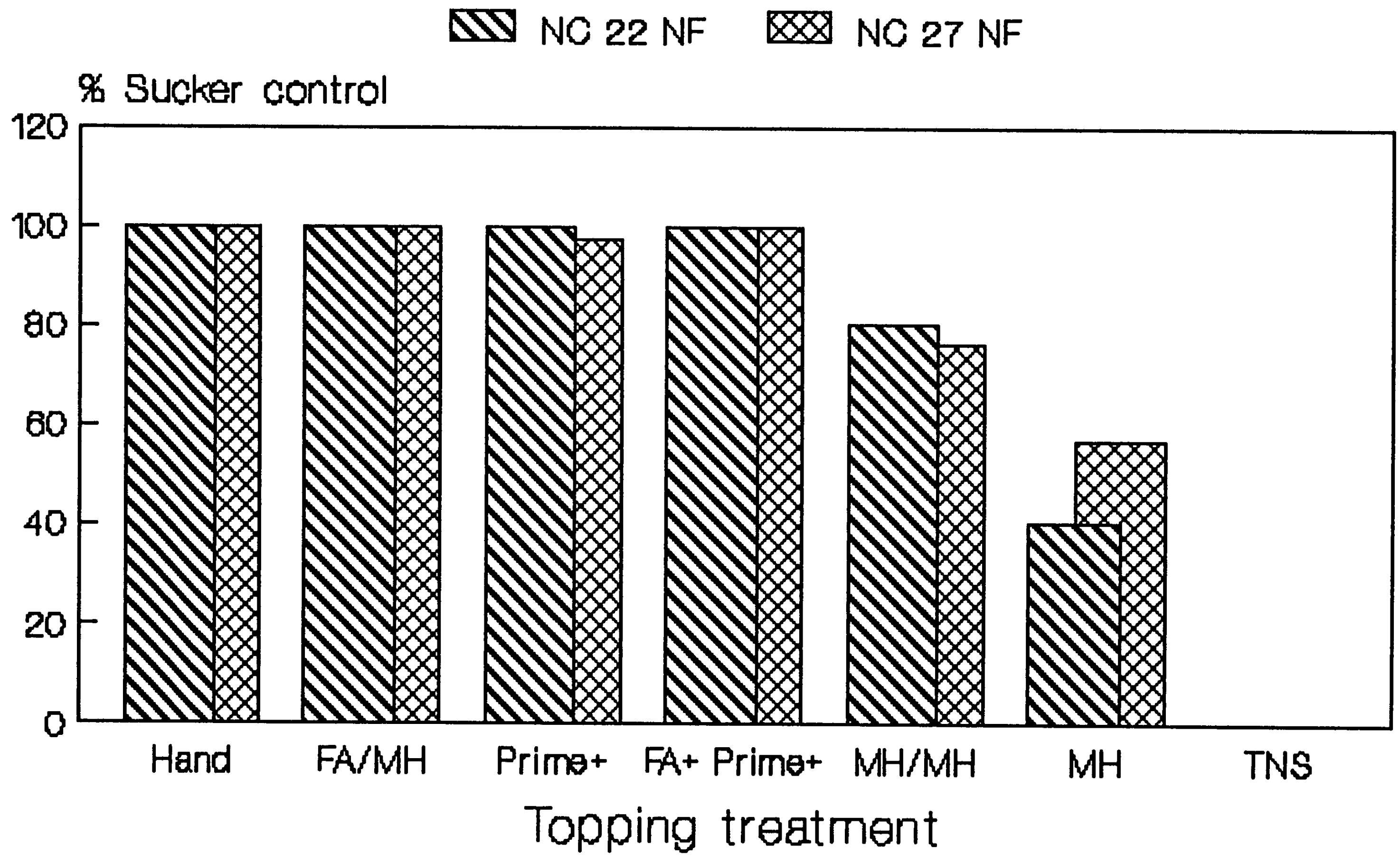

Figure 4. Influence of variety by topping treatment on sucker control in 1988.

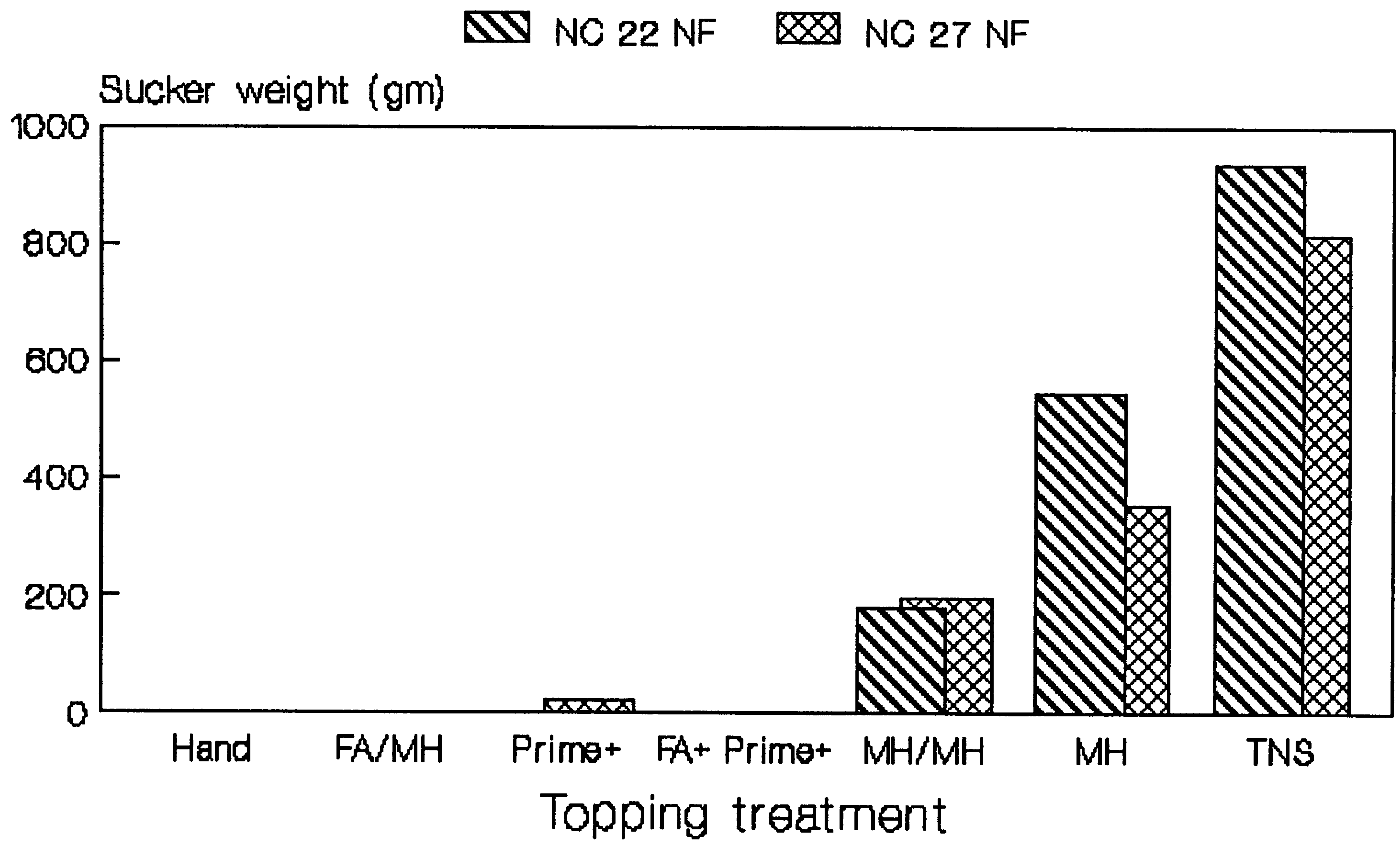

Figure 5. Influence of variety by topping treatment on sucker weight in 1988.

was the changes in leaf chemistry. Chemical topping treatments produced cured leaves with lower total alkaloids and equal or higher reducing sugars than the hand-topped check in both years (Tables 11 and 12). Reducing sugars were adequate in all cases, but the total alkaloids may be too low for desired smoke quality according to Tso (10). The low total alkaloids may be explained by the fact that removal of the apical meristem stimulates nicotine production in the fibrous roots of tobacco plants (5). Tops are not actually removed with chemical topping. Apical dominance may not be broken and nicotine would not accumulate (5, 1). However, Steffens and Mckee (9)obtained no differences in nicotine with chemical topping of Maryland tobacco.

Significant differences in reducing sugar levels were detected between varieties for 1988 (Table 13). NC 22 NF produced a higher percentage of reducing sugars than did NC 27 NF, but all reducing sugar levels were acceptable from a smoke quality standpoint (10).

Summary

Chemical topping has excellent potential for use with mammoth varieties of flue-cured tobacco. The fatty alcohol / maleic hydrazide sequential, the flumetralin - fatty alcohol tank mix, and the flumetralin treatments provided yields, values, grade indices, sucker control, and reducing sugar levels equivalent to the hand-topped control for both NC 22 NF and NC 27 NF. However, these treatments produced lower total alkaloids and slightly smaller leaves than the hand-topped control. Further work needs to be conducted using chemical topping with subsequent mechanical top removal to break apical dominance in an effort to increase the total alkaloids to a more acceptable level.

Maleic hydrazide treatments produced lower yields, values per hectare, sucker control and total alkaloids with both varieties. Maleic hydrazide alone should not be used for chemical topping . However, maleic hydrazide may prove to be an excellent chemical topping agent, if used in conjunction with other sucker control agents such as flumetralin or fatty alcohols.

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