To the Graduate Council:

I am submitting herewith a thesis written by Danny Roland Peek entitled "Chemical Topping of Burley Tobacco". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Masters of Science, with a major in Plant and Soil Science.

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CHEMICAL TOPPING OF BURLEY TOBACCO

A Thesis

Presented for the

Master of Science

Degree

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Danny Roland Peek

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DEDICATION

This thesis is dedicated to my mother, Susie H. Peek. I know she has made many sacrifices that I might be able to get an education. Her prayers and encouragement will always be remembered as a major component in making it possible for me to complete this thesis.

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Philippians 4: 13 "I can do all things through Christ which strengthen me".

ABSTRACT

Topping tobacco (*Nicotiana tabacum* L.) is a procedure that requires the removal of the terminal bud or inflorescence of the plant. Topping tobacco has been a common practice almost since tobacco has been domestically cultivated, due to the desirable effect it has on yield and quality of the tobacco leaf. The objective of this study was to determine if burley tobacco can be chemically topped using common sucker control materials. The burley tobacco variety TN 86 and the non-flowering burley tobacco breeding line BM 16 were used in the research study. Four chemical topping treatments were applied to both burley tobacco lines. These included: KMH; KMH tank mixed with flumetralin (KMH/P+); FST7 tank mixed with flumetralin (FST7/P+); and FST7, followed one week later with a treatment of flumetralin (FST7-P+). These treatments were applied at three different plant growth stages. Chemical treatments were applied at either the 25, 50, or 75 percent button stage for TN 86 and either the 25, 30, or 35 leaf stage of maturity for BM 16. The most effective chemical topping for TN 86 occurred when chemical treatments were applied at the 25 percent button growth stage. Applications at later maturity stages resulted in less effective chemical topping. Compared to the hand topped check, all the chemical topping treatments resulted in reduced yields. Although the most effective topping was achieved at the 25 percent button maturity stage, application of chemicals at this stage resulted in the largest yield reduction. This yield reduction was due to reduced leaf size, which lowered cured leaf weight in the upper portion of the plant. For BM

16, excellent topping was obtained with all of the chemical treatments, regardless of the growth stage at which they were applied. In comparison to the hand topped check, yields of BM 16 were reduced by all chemical treatments when applied at the 25 leaf stage of maturity; however all treatments applied at the 35 leaf stage resulted in increased yields. Although the size of at least the top three leaves of the plant were reduced, regardless of chemical treatment or time of application, yields of BM 16 increased due to the higher number of harvestable leaves.

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CHAPTER I

INTRODUCTION

Tobacco (*Nicotiana* *tabacum* L.) has long been an economically important agricultural crop in Tennessee and other tobacco producing states, despite recent adverse public opinion and concern over health hazards. Tennessee is the third leading state in tobacco production in the United States. For the second consecutive year, tobacco has ranked as Tennessee's number one valued crop at $270.9 million in 1992. This total revenue was derived from 72,200 acres of tobacco harvested, with an average yield of 2,030 pounds acre^{-1} in 1992. Burley tobacco accounted for 64,000 acres of the total acres produced, producing an income of $231.2 million (3).

Because of the importance of burley tobacco to the state's agricultural economy, continued research on methods to improve the efficiency of tobacco production is needed. Since burley tobacco producers have been faced with reduced production quotas and increased production costs, they are forced to employ excellent management practices if the crop is to maintain or increase its profitability. Some of these management practices include proper topping and use of sucker control chemicals.

Topping tobacco is procedure that requires the removal of the terminal bud, which destroys apical dominance. Topping has been a common practice almost since tobacco has been domestically cultivated, due to the desirable effect it has on yield and quality of the tobacco leaf. Early research by Bortner (7) indicated that leaf area is increased by topping, with a disproportionate increase in width. This is thought to be because the midrib expands to maintain a constant ratio of midrib and vascular tissue to lamina area (1). Under favorable weather conditions, topped burley tobacco plants produced 514 kg ha^{-1} more than untopped plants (37).

Currently, topping consists of the manual removal of the flower portion of the plant by removing the apical bud along with the top few leaves. Any suckers (axillary buds) which develop at the junction of the leaf and stalk (leaf axil) are also removed during the topping process. Once apical dominance is destroyed by removing the terminal bud, axillary buds are not inhibited and begin to develop in each leaf axil. Sucker growth is controlled by the application of one or more plant growth regulators applied just prior to, or immediately following, topping. Sucker control compounds are identified as having systemic, locally systemic, or contact modes of action.

The primary objectives of this research were: 1) to determine if burley tobacco could be chemically topped, and suckers effectively controlled simultaneously, using traditional chemical sucker control agents that are commonly used by Tennessee tobacco producers; 2) to determine the most desirable stage of plant maturity at which treatments should be applied to achieve effective chemical topping without sacrificing yield and quality of the tobacco leaf; 3) to evaluate the yield and quality of burley tobacco when chemically topped as compared to conventional topping procedures; and 4) to examine the effectiveness of chemical topping in a traditional flowering burley variety (TN 86) compared to a nonflowering burley breeding line (BM 16).

CHAPTER II

LITERATURE REVIEW

TOPPING

Modern management systems for the production of tobacco require that tobacco be topped (22,25,64). Topping tobacco is a procedure that requires the removal of the terminal bud or inflorescence of the plant. This process removes dominance exerted by the stem apex and allows for reallocation of assimilates from reproductive sinks to other metabolic sinks within the plant such as roots, leaves, and axillary meristems (50). Topping has been identified as the cultural practice that gives tobacco leaves their desired chemical and physical characteristics that lead to high yields of quality leaf (66). Effects induced by topping include increased root growth, improved cured leaf quality, increased size and weight of leaves, and an increase in grower profits (24,53,54,64). As a result of increased root growth, nicotine (which is synthesized in the roots and translocated to other organs) is increased in all parts of the plant. Although nicotine levels are highest in the upper leaves, this effect continues down the plant as topping practices are implemented earlier (1).

Once the terminal bud is removed and apical dominance is destroyed, axillary buds (suckers) develop rapidly to replace the reproductive capabilities of the plant (1,38,50). It is thought that topping interrupts the supply of auxin, which in turn effects other hormones, allowing axillary buds to grow and develop suckers in the upper three or four leaf axils. If these suckers are allowed to grow, they will reestablish apical dominance and suppress sucker growth from lower leaf axils (50,51). Seltmann and Kim (50) studied the anatomy of the upper leaf axils of mature *Nicotiana tabacum* just before topping. They found three potential suckers in each leaf axil, but usually only two develop under commercial tobacco production practices. There appears to be a type of dominance in each leaf axil from the terminal bud. After the terminal bud is removed, the secondary bud assumes dominance within the leaf axil (21). Suckers must be removed or growth inhibited to maximize leaf weight and quality. Energy and nutrients required for the growth of the buds is redirected into the development of the leaves of the plant, if axillary bud growth is inhibited.

The effects of stage of floral development at time of topping have been extensively investigated on many different types of tobacco. Marshall and Seltmann (39) noted that plants topped at the button stage, with suckers effectively controlled, resulted in higher yields of quality leaf. Any delay in topping, beyond the early flower stage, resulted in an average yield loss of approximately 25 pounds per acre (lbs/acre) per day in flue-cured tobacco. However, Seltmann et al. (51) found little or no difference in yield and quality of burley tobacco topped in early-bloom, compared to plants topped at mid-bloom. Collins et al. (17) reported that fewer elongated suckers exist on plants topped at the early flower stage. They also reported that 56 percent fewer labor hours were required to top and sucker plants in preparation for applying chemicals in this stage as compared to topping at the full flower stage seven to 10 days later.

Topping is generally done by hand and some evidence indicates approximately 17 worker hours per hectare (hr ha^{-1}) is required (37). However, hand suckering can be much more labor intensive, requiring from nine to 92 hr ha^{-1} depending on environmental factors and time of topping (28). Because hand suckering tobacco is disagreeable, costly, and very time consuming, chemical sucker control agents have been enthusiastically accepted by tobacco producers throughout the world.

CHEMICAL INHIBITION OF SUCKER GROWTH

Maleic Hydrazide. In tobacco production, chemical sucker control plays a major role in the production of quality leaf, and has virtually replaced hand suckering of the crop. One of the earliest and most effective means of chemically controlling suckers in tobacco was maleic hydrazide (1,2-dihydro - 3,6 - pyridazinedione. Maleic hydrazide (MH) was first synthesized in 1895 by Curtis and Fosterburg (28). However, it was not until 1949 that Schoene and Hoffman reported its inhibitory effect on plant growth (48). Since then the use of MH has expanded to several economically important crops such as potatoes, onions, carrots, radishes, sugar beets, and other crops (28). In 1951, Peterson (45) investigated controlling tobacco sucker growth with maleic hydrazide. He evaluated solutions of three salts and determined that 0.106 molar solutions of the potassium and diethanolamine salts of MH produced excellent sucker control. Although Peterson's (45) results indicated greater levels of sucker control with diethanolamine salts at lower concentrations, later research showed unacceptable high levels of MH residue (over 80 ppm) in the cured leaf (14). Currently, MH is manufactured commercially by reacting the potassium salt of hydrazine with maleic anhydride (KMH) (39). It is marketed by Uniroyal Chemical Company under the trade name Royal MH-30™ (39), and by several other companies under various trade names.

MH is applied as a fine mist over the upper one third of the plant to thoroughly cover the upper leaves (39). It must be absorbed by the leaves to be effective, and this process is enhanced when applied to rapidly growing plants under high humidity (52). After MH enters the plant, it is readily translocated throughout the plant in both the phloem and xylem tissues (systemic) (28,52,68). Although the mode of action for MH has been studied for over 30 years, the biochemical processes through which it affects plant development are still not completely understood (12). Some evidence indicates that MH inhibits cell division and subsequent sucker growth by inhibiting DNA and RNA synthesis (41,42,68); however, actively growing cells will enlarge and differentiate (52).

MH has been found to provide excellent sucker control and allow yields comparable to clean suckering by hand without adversely affecting quality (13). Through treatment evaluations, Seltmann (49) found that the highest yield and value per acre values for burley tobacco were obtained when plants were topped and treated with MH. However, since MH is so highly mobile in the plant, manufacturers soon expressed concern that MH would induce physical and chemical changes that would be harmful to smoke quality and flavors of certain tobacco types (2,20). One of the most pronounced aspects of MH is its effect on the sugar-to-nicotine-ratio. Much evidence exists that MH increases the sugar to nicotine ratio, which produces an undesirable flavor in tobacco (6,20,24,40,57).

A major concern about the use of MH on tobacco is the presence of residues in the cured leaf. MH is considered very stable, and for the most part, remains unchanged in the tobacco plant. Fourteen to 18 percent of applied MH may be present in the plant as metabolites, of which more than 90 percent is a ß-glucoside (23). MH applied at labeled rate (170 mg ai plant^{-1}) to flue-cured tobacco resulted in average residues ranging from 31 to 156 ppm in the cured leaf (29). In burley tobacco, MH residues averaged 48 ppm with a range from zero to 270 ppm depending on environmental conditions, time between application and harvest, and amount of MH applied (52). The European Economic Community has set maximum residue limits for MH at 70 ppm (9) in the cured leaf. These concerns have resulted in the investigation of other chemicals for the control of axillary bud growth in tobacco.

Fatty Alcohols. Steffens et al. (58) determined that fatty alcohols (FAs) with chain lengths of C_9, C_{10}, and C_{11} effectively inhibited axillary and terminal bud growth in tobacco plants. In addition, FAs with chain lengths from C_8 to C_{14} were effective, depending on the concentration of the surfactant, but the C_{10} homolog was shown to be the most effective for controlling suckers (58,59). Increased effectiveness was also associated with increased yield and crop returns. Rosa and Caughill (47) supported this evidence by concluding that FAs with C_8 and C_{10}

homologs are among the most effective of several FAs evaluated; these compounds are now used commercially as contact sucker control agents in the U.S. and other tobacco producing countries (46,58,60). Residues are normally less than 2.6 ppm for both the FA and surfactant (61).

FAs are applied as relatively coarse sprays and must run down the stalk to contact each leaf axil to kill the immature suckers. Since these materials must come in contact with the suckers to be effective, they are referred to as a contact suckering agents. These FAs are phytotoxic to young meristematic tissue, but cause little or no injury to more mature tissue such as leaves (52). FAs with the aid of surfactants are able to penetrate the cuticular layer of the meristematic region of the axillary buds. The axillary buds will then turn brown and are killed by cell disruption and desiccation (52). However, without the proper type and amount of surfactant, the esters and alcohols exhibit nonselective killing of tissue, which results in low effectiveness and marked leaf injury (54).

A major drawback to the acceptability of FA compounds is that their effectiveness is inconsistent and is generally short term (52). Seltmann (49) conducted a three year study on the effectiveness of FAs for sucker control in flue-cured tobacco. He found that one, two, and three sequential applications at labeled rates resulted in unsatisfactory sucker control of 27, 36, and 48 percent, respectively. In burley and Maryland tobacco, one application of FAs may not be sufficient for acceptable sucker control because secondary suckers may begin to develop before harvest. In contrast, MH has been reported to usually provide acceptable sucker control in these tobacco types until the crop is harvested (52). Since the harvesting process continues six to eight weeks in flue-cured tobacco, neither MH or FA will provide effective sucker control until harvesting is completed (26). However, research indicates that a program of sequential applications of FA followed by systemic chemical such as MH provides excellent sucker control and increased yields (18,19,33,47).

In 1976 a commercial formulation of a C_{10} FA (n-decanol) and the potassium salt of MH (KMH) was developed by Calman J. Kish, and later marketed by Fair Products, Inc., under the trade name FST7™ (4). FST7 was first registered for use on tobacco in 1978 and is currently labeled for controlling axillary buds in tobacco (4). The material should be applied immediately after topping as a coarse spray covering the upper 1/3 of the plant and allowed to run down the stalk, making contact with each leaf axil (4). FST7 is considered both a contact and systemic sucker control agent since one application will kill existing small suckers and provide long term sucker control by acting systemically to inhibit cell subdivision (4). According to label recommendations, 431 mg of active FST7 should be applied per plant (4). This is accomplished by applying 15 to 20 ml of diluted FST7 (i.e. 3:47 v/v dilution of commercial formulation to water) to each plant (4).

Flumetralin. Flumetralin {2-chloro-N-[2,6-dinitro-4-(trifluoromethyl)phenyl]-N-ethyl-6-fluorobenzenemethanamine} is one of the most recently registered chemicals for sucker control in tobacco. It was originally developed by Wilcox et al. (64) as reported in 1977 and is currently marketed by Ciba-Geigy Corporation under the trade name Prime+™ (15,16). Flumetralin belongs to the dinitroaniline family of agricultural chemicals. The dinitroanilines are persistent in soils and are considered to be among the least mobile herbicides (10,27). The effect that dinitroaniline herbicides have on root development of susceptible species is similar to the effect that flumetralin has on sucker growth (5,15,43). Once flumetralin is absorbed into the cells of the axillary meristems of tobacco, it binds to tubulin and prevents it from forming microtubules, effectively inhibiting spindle fiber development and disrupting mitosis (5,15,36,43).

Studies have indicated that ^{14}C-labeled flumetralin moves very little, if any, from the site of application (10,15,27,43). Flumetralin is therefore considered to be a locally systemic compound. Like the FAs, it must reach each leaf axil to be most effective (53). According to label recommendations flumetralin can be applied as either a directed spray or as a hand application at rates of 0.8 to 1.4 kg ai ha^{-1} (16). However, hand application methods have been reported to give a higher degree of sucker control than tractor mounted sprayer applications (34).

Research indicates that flumetralin can provide equivalent or superior sucker control in comparison to MH (11,31,32,62). Steffens (53) reported that 30 mg $plant^{-1}$ of flumetralin (then CGA-41065) alone was as effective for controlling suckers as 170 mg $plant^{-1}$ of MH, and more effective than 100 mg MH alone. However, a combination of flumetralin and MH was more effective than either MH or flumetralin alone (53). He also noted a high level of sucker control in flue-cured tobacco from tank mixes of KMH and flumetralin. It was later shown that tank mixes of half the label rates of flumetralin (9.5 liters ha^{-1}) and KMH (14.25 liters ha^{-1}), applied at the early flower stage, resulted in 99 percent sucker control (63). Flumetralin provided effective sucker control in flue-cured tobacco when applied at the early flower stage at rates of 1.4 kg/ha. Applied at the button stage, it provided up to 100 percent effective sucker control, however, the most consistent treatment for sucker control was the application of FA at 6.5 kg ha^{-1} at the button stage, followed by a sequential tank mix of flumetralin and MH (63). Jones and Rideout (30) noted that the concentration and delivery volume of flumetralin significantly affected the level of sucker control obtained, and subsequently the yield of flue-cured tobacco. A comparison of two treatments which contained 57 mg ai $plant^{-1}$ of flumetralin demonstrated that a 2 percent v/v concentration of flumetralin applied at a delivery volume of 20 ml $plant^{-1}$ provided over 98 percent sucker control, whereas a 4 percent v/v solution applied at 10 ml $plant^{-1}$ provided only about 80 percent sucker control (30).

It has been well documented that chemicals can be utilized to effectively control or inhibit axillary bud growth. An ideal suckering agent would be a chemical applied as a single application that simultaneously inhibited terminal bud development (topping), as well as axillary buds (suckers), with no adverse effects on leaf yield and quality.

CHEMICAL TOPPING OF TOBACCO

Although there are no commercial chemicals manufactured specifically for topping tobacco, some research has been conducted with different commercial tobacco types to evaluate chemicals for this purpose (38,55,58,62,65). Steffens et al. (58) evaluated FAs (C_9, C_{10}, and C_{11}) for their ability to inhibit tobacco axillary and terminal buds. They determined that the terminal bud could be inhibited if chemicals were applied before the flowers opened. Suckers could also be killed if the chemicals were allowed to drain down the entire stalk making contact with each leaf axil (58). The most effective alcohol tested was 1-decanol.

In a later study, Steffens and McKee (55) investigated the chemical topping of Maryland tobacco. They reported that day-neutral Maryland tobacco was effectively chemically topped when the spray emulsion of 1-decanol was applied at the button stage of plant maturity. The chemically topped tobacco plants yielded significantly more cured leaf and returned more dollars per acre compared to tobacco hand topped and suckered at the full bloom stage.

Wolfe (65) compared burley tobacco topped and suckered by chemicals and with tobacco suckered by hand. Results of this study agreed with results from previous research, suggesting that the FA 1-decanol would provide excellent terminal bud inhibition and good sucker control. When compared with three commercially available MH formulations and one fatty alcohol formulation, marketable leaf from the 1-decanol treated plots were not significantly different in yield or dollar value per acre.

Whitty (62) looked at the use of chemicals for topping and controlling suckers in non-flowering flue-cured tobacco. He evaluated a FA, MH, and flumetralin for efficacy of topping and sucker control in two non-flowering tobacco selections. Flumetralin applied alone or in combination with a FA inhibited apical dominance in almost all plants. Some of the smaller, upper leaves of treated plants were distorted. Excellent sucker control was obtained and cured leaf yields from the chemically treated plants were generally unaffected.

In a two year study, Long (38) evaluated the effects of chemically topping mammoth (photoperiod sensitive) cultivars of flue-cured tobacco. In the first year, chemical topping treatments included: hand topped with an application of FA (4 percent v/v) plus KMH (2.7 kg ha^{-1}) for sucker control; KMH at 2.7 kg ha^{-1}; flumetralin at 3.7 kg ha^{-1}; and FA (Off Shoot-T) at 4 percent v/v. Treatments were consistent for the second year with the exception of two additional treatments, topped not suckered and a tank mix of FA (4 percent v/v) plus flumetralin (3.7 kg ha^{-1}). All treatments were applied when the 18th to 20th leaf on the majority of the plants in a plot reached 15 cm in length. Suppression of terminal buds (topping) was excellent for all treatments. Inhibition of axillary buds (suckers) was successful with all treatments except for the single applications of KMH for both years. Yields from all plants chemically topped by flumetralin, flumetralin + FA, and FA tank mixed with KMH compared favorably to plants hand topped. However, plants chemically topped with KMH alone produced lower yields. Yield reduction was attributed to poor sucker control.

CHAPTER III

MATERIALS AND METHODS

A two-year study was conducted to evaluate several chemical sucker control compounds for their ability to inhibit terminal bud growth (chemical topping), as well as axillary bud growth (suckers), in burley tobacco. The chemical compounds were applied to flowering and non-flowering burley tobaccos at various stages of maturity to determine their relative effectiveness. The chemical treatments were also compared with conventional topping methods (which utilized early flower topping and one application of maleic hydrazide + Flumetralin) to determine their advantages and/or disadvantages in terms of yield and quality of burley tobacco. The study was conducted at the University of Tennessee Tobacco Experiment Station at Greeneville, Tennessee, in 1992 and 1993.

To determine the effectiveness of chemical topping of burley tobacco, several treatments were investigated to examine their interrelationships when used in conjunction with one another. Combinations of plant maturity at time of chemical application, type of chemical agent or agents used, rate of chemicals applied, and method of chemical application define a particular topping treatment used in this research. The chemical topping treatments evaluated in this study were selected based primarily on their ability to inhibit axillary bud growth, and their availability to Tennessee burley tobacco producers.

EXPERIMENTAL DESIGN

Two burley varieties having distinctively different flowering habits were used to evaluate the effectiveness of the chemical treatments used in the study. The first variety was TN 86, a late flowering cultivar that is widely used for burley tobacco production. TN 86 was chosen because it is a late maturing variety with the ability to produce a relatively high number of leaves. The second variety used was Burley Mammoth 16 (BM 16), a non-flowering burley breeding line that has not been released for commercial use. BM 16 was utilized because non-flowering genotypes, commonly referred to as "mammoths", remain vegetative until the shorter photoperiods of late summer when they are induced to flower. This delayed flowering results in the production of an extremely high number of leaves. The usual practice with mammoth cultivars is to top to a given leaf number while the plant is still in the vegetative state (38). A high number of leaves was hypothesized to be necessary for satisfactory chemical topping in order to compensate for any stunting or distortion that may occur in the upper leaves of treated plants.

Four chemical sucker control treatments were evaluated in the study. The first treatment (KMH) was Royal MH-30™ applied at 180 mg ai plant^{-1}, which is within the label recommended rate for burley tobacco. Royal MH-30™ is the potassium salt of maleic hydrazide, {1,2-dihydro-3,6,-pyridazinedione}, which acts as a systemic growth regulator. The second treatment (FST7-P+) was a sequential application of FST7 applied at the recommended rate of 431 mg ai plant^{-1}, followed one week later with an application of Prime+™ at 22 mg ai plant^{-1} (half the recommended rate).

FST7™ is a commercial formulation of KMH and C_{10} fatty alcohol (n-decanol). Prime+™ is a formulation of the dinitroaniline, flumetralin [2-chloro-N-{2,6-dinitro-4-(trifluoromethyl)phenyl}-N-ethyl-6 fluorobenzene-methanamine}. The third treatment (KMH/P+) was a tank mix of a full rate of KMH and a half rate of Prime+. The fourth treatment (FST7/P+) was a tank mix of a full rate of FST7 and a half rate of Prime+.

Each of the chemical treatments was applied at three plant maturity stages. These stages differed for each tobacco variety. Maturity stages for TN 86 were defined as when 25, 50, or 75 percent of the plants had reached the button stage of flowering. The button stage is considered to be the point at which the floral bud is visible but not elongated and not open. The three maturity stages defined for BM 16 were points at which the plant had 25, 30, or 35 leaves that were at least 15.2 cm in length.

All chemical treatments were compared to check treatments, which were different for each tobacco variety. TN 86 check plots were hand topped when 50 percent of the tobacco plants exhibited at least one open flower; KMH/P+ was applied immediately following topping. BM 16 check plots were hand topped when plants had produced an average of 30 leaves at least 15.2 cm in length, with KMH/P+ applied immediately following topping. A summary of treatments is listed in Table 1.

A split split-plot experimental design arranged in a randomized complete block with four replications was used for the study. Varieties were assigned to whole plots.

Table 1. Description of chemical topping treatments used in burley tobacco, Tobacco Experiment Station, Greeneville, Tennessee, 1992 - 1993.

VARIETIES	MATURITY[a] STAGES	CHEMICAL TREATMENTS[b]
TN 86	25 % button	KMH at 180 mg ai plant^{-1} in a 20 ml solution
	50 % button	KMH at 135 mg ai plant^{-1} and Flumetralin at 21.6 mg ai plant^{-1} in a 15 ml solution
	75 % button	
		FST7 at 431 mg ai and flumetralin at 21.6 mg plant^{-1} in a 15 ml solution
BM 16 followed flumetralin	25 Leaves	FST7 at 431 mg ai plant^{-1} in a 15 ml solution by (week later) a sequential treatment of 21.6 mg ai plant^{-1} in a 15 ml solution
	30 Leaves	
	35 Leaves	
Check[c] TN 86	50 % bloom	KMH at 135 mg ai and flumetralin at 21.6 mg plant^{-1} in a 15 ml solution
Check BM 16	30 Leaves	KMH at 135 mg ai and flumetralin at 21.6 mg plant^{-1} in a 15 ml solution

[a]Maturity stage at which chemical applications were made were dependent on the variety. The term "percent button" was used for TN 86 to describe the plants reproductive development preceding any flower formation. "Leaf number" was used to describe the development of BM 16. When plots reached the designated maturity stages, chemical applications were made.

[b]Rates given in actual formulation. All chemical treatments were applied with a hand held Hudson sprayer calibrated to deliver precise volumes.

[c]The term "check" refers to plots that were topped according to conventional practices. For TN 86, check plots were hand topped when at least 50 percent of the plants exhibited one open corolla. For BM 16, check plots were hand topped when plants averaged 30 leaves.

Sub-plots were maturity or growth stages at which chemical treatments were applied. Sub-sub plots were chemical treatments. Treatment significance was tested by analyses of variance at the $\alpha=.05$ level. Mean separations among treatments were carried out using least significant difference (LSD) at the 95 percent probability level.

FIELD EXPERIMENTS FOR 1992-1993

Preliminary soil preparation was accomplished using conventional cultural practices (fall plowed and winter fallowed). Soil preparation in the spring included ripping and dragging the fields. Prior to transplanting, the insecticide, chlorpyrifos was applied at 2.24 kg ai ha^{-1} and incorporated into the soil. Approximately five days prior to transplanting, the herbicide, pendimethalin was applied at 1.12 kg ai ha^{-1}. The herbicide, napropamide was applied at one pound per acre together with the fungicide, metalaxyl at 2.24 kg ai ha^{-1}. These compounds were not incorporated by tillage; however, rainfall the following morning served to incorporate the chemicals. Acephate, an organophosphate insecticide, was applied at 0.84 kg ai ha^{-1} through the transplant water.

Tobacco was transplanted May 22, 1992 in a Nolichucky silt loam soil (Fine-Loamy, Siliceous, Mesic Typic Paleudults). In 1993, the tobacco was transplanted May 17 in a Waynesboro silt loam soil (Clayey, Kaolimitic, Thermic Typic Paleudults). Application and rates of herbicides, fungicides, and insecticides were the same for 1993 as in 1992, with the exception that chlorpyrifos was not applied in 1993. Throughout the growing season Acephate was applied foliarly at 0.84 kg ai ha^{-}

[1] as required to maintain insect populations below established economic thresholds. Plots were cultivated and hand-hoed as needed.

Fertilization applications were the same for both years. The addition of nitrogen, phosphorus, and potassium was applied as a mixed fertilizer (9-18-27) at the rate of 1120 kg ha^{-1} of N-P-K. Additional nitrogen (336 kg ha^{-1}) was applied as ammonia nitrate (34-0-0) two weeks after transplanting. The soil pH for both years was maintained between 6.0 and 6.5 by the addition of dolimitic limestone. Each plot consisted of approximately 32 plants; however actual stand counts were taken to establish a precise plant population. Plants at the end of each plot row were destroyed to minimize data biases due to plant competition, leaving approximately 30 harvestable plants. Each plot row was 13.7 m long with 107 cm spacings between rows and 46 cm spacings between plants within the row, for both years. All plot rows were bordered on adjacent sides, with plants of the same variety as the plot row, to reduce undue data biases caused by plant competition and to prevent the drift of chemical treatments from another plot.

CHEMICAL APPLICATION METHODS

Prior to the application of chemical treatments, plant maturity data were collected daily to ensure that the treatments were applied to each plot as near to the desired maturity stage as possible. For TN 86, the percentage of plants judged to be in the button stage was determined across replications for each scheduled treatment. The same procedure was used for TN 86 check plots, substituting bloom counts for button counts. For BM 16, leaves greater than 15.2 cm in length were counted on the first ten normal plants of each plot row. Abnormally stunted plants were avoided.

Because variability for plant maturity occurred among the plots and across replications, it was not possible to apply scheduled treatments to all plots at precisely the desired maturity stage. Treatments were therefore applied to all plots when the average maturity had reached the desired stage. All chemical treatments were applied with a Hudson hand held sprayer boom attached to 1.9 L jar. All sprayers were calibrated to deliver 15 ml/plant of solution, with the exception of sprayers used to apply KMH which was calibrated to deliver 20 ml/plant of solution. Each treatment except KMH was applied as a coarse spray directed to the bud portion of the plant; the material was allowed to run down the stalk making contact with each leaf axil. KMH was applied as a fine mist sprayed over the upper portion of the plant. Check plots for both TN 86 and BM 16 were hand topped when the plants reached the appropriate maturity stage and treated with KMH/Prime+ for sucker control.

DATA COLLECTED AND TREATMENT EVALUATIONS

Topping. Treatments were evaluated two weeks after application to determine the percentage of plants successfully topped. The terminal bud was removed from each plant that was not successfully chemically topped just prior to harvest for ease of harvest and curing purposes. Since check plots were hand topped, percentages were not calculated for effective topping. Plants from all plots were harvested five weeks after topping, in the order they were treated, to achieve maximum yields (67).

Sucker Control. Tobacco sucker control was evaluated approximately 34 days after treatment application, one day preceding harvest. Suckers from each plot row were hand harvested, counted, and fresh weights recorded. The percentage of plants with suckers, number of suckers per plant, and average sucker weight were calculated based on original stand counts.

Tobacco Yield and Quality. Data were obtained from each experimental plot to determine the effects of the different treatments on yield and quality. At harvest, approximately 30 plants were cut, placed on sticks, and allowed to field wilt for one day. The tobacco was cured in a conventional 4 tier burley tobacco curing barn. After curing, leaves from every stalk were stripped, weighed, and given a federal burley tobacco grade by a USDA inspector. Yield per acre was calculated by multiplying yield per plant by plant population. A grade index was calculated, based on the USDA grades, for each plot. The index indicates overall cured leaf quality, with higher numerical values denoting better quality (8). During stripping, ten plants were selected from each plot for measurement of agronomic characters. Data were recorded for leaf number, length and width of the top three leaves, stalk length, and stalk weight to determine any negative or positive effects associated with chemically topping burley tobacco.

CHAPTER IV

RESULTS AND DISCUSSION

EFFECTIVENESS OF CHEMICAL TOPPING

Data for the percentage of plants that were effectively topped by the chemical treatments are presented in Table 2. Chemical topping was much more effective in BM 16 than in TN 86 during both years of the study. For BM 16, excellent chemical topping was obtained with all chemical treatments, regardless of the stage of plant maturity at which the treatments were applied. For both years, the effectiveness of topping, averaged across chemical treatments or maturity stages, was above 99 percent. The least effective individual treatment, KMH/P+ applied at the 30 leaf stage in 1992, resulted in approximately 95 percent topping. The effectiveness of chemical topping in BM 16 can be attributed to its non-flowering growth habit. Since BM 16 remained vegetative until chemical treatments had been applied, all treatments resulted in excellent topping regardless of stage of plant maturity. These results are consistent with those obtained in studies conducted on chemical topping of flue-cured tobacco (38,62).

The effectiveness of chemical topping in TN 86 was much more inconsistent than it was in BM 16. In general, chemical topping of TN 86 was more effective in 1993 than it was in 1992. Topping effectiveness ranged from 37 to 91 percent in

Table 2. Effectiveness of chemical treatments in topping TN 86 and BM 16 burley tobacco at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Plants topped		Leaf	Plants topped	
Treatment[a]	button	1992	1993	number	1992	1993
		Percent			Percent	
Check[b]	50	-	-	30	-	-
FST7/P+	25	84.5	82.4	25	98.5	100
FST7-P+	25	84.9	86.5	25	99.3	100
KMH/P+	25	91.1	87.0	25	100	100
KMH	25	87.8	90.1	25	100	100
FST7/P+	50	74.3	72.2	30	100	99.0
FST7-P+	50	54.6	76.3	30	96.2	98.5
KMH/P+	50	56.8	88.5	30	94.6	99.2
KMH	50	53.7	94.3	30	99.2	100
FST7/P+	75	40.8	76.2	35	100	99.2
FST7-P+	75	37.3	77.6	35	99.2	100
KMH/P+	75	40.3	81.8	35	100	99.3
KMH	75	37.0	77.2	35	99.1	99.2
LSD (.05)		18.2	11.0		18.2	11.0
		Means for maturities averaged across treatments				
Check	50	-	-	30	-	-
Mean	25	87.1	86.5	25	99.4	100
Mean	50	59.9	82.8	30	97.5	99.2
Mean	75	38.9	78.2	35	99.6	99.4
LSD (.05)		16.0	5.7		16.0	5.7
		Means for treatments averaged across maturities				
Check	50	-	-	30	-	-
FST7/P+	Mean	66.6	76.9	Mean	99.5	99.4
FST7-P+	Mean	58.9	80.1	Mean	98.2	99.5
KMH/P+	Mean	62.8	85.8	Mean	98.2	99.5
KMH	Mean	59.5	87.2	Mean	99.5	99.7
LSD (.05)		10.5	6.3		10.5	6.3

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.
[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

1992, depending on stage of plant maturity; in 1993 the range was from 72 to 94 percent.

The effectiveness of topping decreased in both years as application of chemical treatments was delayed beyond the 25 percent button stage of maturity. The decrease in effectiveness due to delayed application of chemical treatments was much more pronounced in 1992 than in 1993. For both years of the study, the average effectiveness of chemical topping was near 87 percent at the 25 percent button stage of maturity. However, the percentage of plants effectively topped was significantly lower when chemical application was delayed to the 75 percent button stage. In 1992 all maturity stages at which chemical treatments were applied were significantly different from each other, with effectiveness decreasing from 87 percent at the 25 percent button stage of plant maturity, to 39 percent at 75 percent button. Similar trends were observed in 1993, but the decrease in effectiveness was not as great. In 1993 there was a significant decrease of 8 percent in topping effectiveness when application was delayed from the 25 to 75 percent button stage. The decreased effectiveness of chemical topping that occurred with advanced maturity is consistent with research conducted by Steffens (55,58), which concluded that chemical topping treatments must be applied at an early stage of bud development, prior to flower opening, in order to be effective.

All of the chemical treatments were most effective when applied at the 25 percent button stage of plant maturity, with the exception of KMH applied at 50 percent button in 1993. Differences in effectiveness of topping among the four chemical treatments applied to TN 86 were relatively small and not significant in 1992. The range for effective topping was from 67 percent with FST7/P+ to 59 percent with FST7-P+. Although KMH was the least effective treatment in 1992, it was the most effective in 1993. The KMH treatment was 87 percent effective; this was significantly better than either FST7/P+ or FST7-P+, which resulted in 77 and 80 percent topping, respectively.

EFFECTS OF CHEMICAL TOPPING ON SUCKER CONTROL

Percent of Plants with Suckers. The percentage of plants having suckers was generally lower in 1992 than 1993 for both TN 86 and BM 16 (Table 3). The 1993 growing season was relatively dry, which often results in poor sucker control. The percentage of TN 86 plants with suckers was significantly lower at the 25 percent button stage than either the 50 or 75 percent button stages. However, the 50 and 75 percent button stages were not significantly different. The increased sucker incidence that occurred in TN 86 when the treatments were applied at later maturity stages is likely due to the higher number of plants that were in flower. Apical dominance is eliminated at flowering, allowing plants to develop suckers prior to chemical treatment. The flowers may also have caused reduced amounts of the chemicals to reach the leaf axils or be absorbed by the leaves.

The percentage of BM 16 plants with suckers at the 25 leaf stage was a least 17 percent less than either the 30 or 35 leaf stages; however, this difference was not significantly different. When BM 16 was allowed to produce 30 to 35 leaves, stalk

Table 3. Effects of chemical topping treatments and plant maturity stages on percentage of plants with suckers for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Plants with suckers		Leaf	Plants with suckers	
Treatment[a]	button	1992	1993	number	1992	1993
		Percent			Percent	
Check[b]	50	20.2	15.3	30	11.3	9.6
FST7/P+	25	1.5	22.9	25	7.2	26.3
FST7-P+	25	1.5	16.5	25	1.5	24.1
KMH/P+	25	1.6	33.5	25	4.7	25.3
KMH	25	44.0	72.9	25	47.4	87.4
FST7/P+	50	12.6	27.0	30	20.4	15.0
FST7-P+	50	16.3	15.7	30	8.0	8.3
KMH/P+	50	44.3	25.7	30	18.5	16.1
KMH	50	68.7	90.2	30	21.9	95.6
FST7/P+	75	9.6	23.7	35	12.9	5.5
FST7-P+	75	28.9	35.8	35	3.4	8.3
KMH/P+	75	23.8	28.9	35	41.1	13.0
KMH	75	63.1	94.0	35	86.9	91.8
LSD (.05)		19.6	17.2		19.6	17.2
		Means for maturities averaged across treatments				
Check	50	20.2	15.3	30	11.3	9.6
Mean	25	12.1	36.4	25	15.2	40.8
Mean	50	35.5	39.6	30	32.2	33.7
Mean	75	31.4	45.6	35	36.1	29.6
LSD (.05)		17.7	15.6		17.7	15.6
		Means for treatments averaged across maturities				
Check	50	20.2	15.3	30	11.3	9.6
FST7/P+	Mean	7.9	24.5	Mean	13.5	15.6
FST7-P+	Mean	15.6	22.7	Mean	4.3	13.6
KMH/P+	Mean	23.2	29.3	Mean	21.4	18.1
KMH	Mean	58.6	85.7	Mean	72.1	91.6
LSD (.05)		13.4	11.7		13.4	11.7

[a] FST/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.

[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

height was as much as 150 cm. This made the application of KMH directly over the top of the plant difficult and may have allowed suckers to develop in the top portion of the plant. Maturity stages had no significant effect on percentage of plants with suckers for either TN 86 or BM 16 in 1993.

Significant chemical treatment effects on the percentage of plants with suckers were detected among several treatments. In 1992, only 7.9 percent of TN 86 plants treated with FST7/P+ produced suckers. This was significantly lower than KMH/P+ or KMH which had 23 and 59 percent of plants with suckers, respectively.
KMH resulted in a significantly higher percentage of plants having suckers for both varieties each year. This is likely a result of the five week time interval between chemical application and harvest. KMH will only effectively control suckers for three to four weeks.

In 1993, checks for both TN 86 and BM 16 had a lower percentage of plants with suckers than any of the other treatments. The check was significantly lower than KMH/P+ and KMH for TN 86 and significantly lower than KMH for BM 16. This was likely due to the routine removal of the larger suckers in the top of the plant as part of the standard, recommended topping procedure for burley tobacco. The chemical sucker treatments may have failed to control the small suckers in the top of the treated plants due to the dry growing season.

Number of Suckers per Plant. The stage od plant maturity at time of chemical application had little effect on the number of plants with suckers (Table 4).

Table 4. Effects of chemical topping treatments and plant maturity stages on number of suckers per plant for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Suckers plant^{-1}		Leaf	Suckers plant^{-1}	
Treatment[a]	button	1992	1993	number	1992	1993
		No.			No.	
Check[b]	50	0.28	0.31	30	0.21	0.28
FST7/P+	25	0.02	0.42	25	0.20	0.30
FST7-P+	25	0.04	0.26	25	0.03	0.40
KMH/P+	25	0.02	0.52	25	0.08	0.33
KMH	25	2.19	4.18	25	2.90	9.98
FST7/P+	50	0.45	0.45	30	1.49	0.25
FST7-P+	50	0.22	0.20	30	0.16	0.18
KMH/P+	50	0.97	0.40	30	0.54	0.33
KMH	50	4.59	5.99	30	7.49	10.4
FST7/P+	75	0.13	1.22	35	0.69	0.13
FST7-P+	75	0.55	1.46	35	0.12	0.14
KMH/P+	75	0.57	1.18	35	1.94	0.25
KMH	75	3.68	12.1	35	4.20	6.22
LSD (.05)		1.88	2.55		1.88	2.55
		Means for maturities averaged across treatments				
Check	50	0.28	0.31	30	0.21	0.28
Mean	25	0.6	1.34	25	0.80	2.75
Mean	50	1.6	1.76	30	2.40	2.79
Mean	75	1.2	3.99	35	1.70	1.68
LSD (.05)		1.5	1.31		1.5	1.31
		Means for treatments averaged across maturities				
Check	50	0.28	0.31	30	0.21	0.28
FST7/P+	Mean	0.2	0.70	Mean	0.80	0.23
FST7-P+	Mean	0.3	0.64	Mean	0.10	0.24
KMH/P+	Mean	0.5	0.70	Mean	0.90	0.30
KMH	Mean	3.5	7.42	Mean	4.90	8.87
LSD (.05)		1.3	1.74		1.3	1.74

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.

[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

The number of suckers per plant was higher for all treatments in 1993 because of the dry growing season. In 1992 and 1993, the number of suckers per plant for TN 86 followed a trend of slightly increasing as chemical treatments were delayed beyond the 25 percent button maturity stage. However, when compared to the hand topped check all maturity stages resulted in an increased number of suckers per plant. The check for TN 86 developed significantly fewer suckers in 1993 than plants treated at either the 50 or 75 percent button maturity stage. Plants treated at the 75 percent button stage produced significantly more suckers per plant than treatment at any other maturity stage. This difference in the number of suckers at the 75 percent button stage may be attributed to the high number of suckers per plant for the plots treated with KMH.

Applying the chemical treatments to BM 16 at the 25 leaf stage resulted in 0.8 suckers per plant in 1992. Delaying the application of chemical treatments to the 30 leaf stage caused a significant increase of 1.6 suckers per plant. The check for BM 16 developed an average of two fewer suckers per plant than plants treated at the 30 leaf maturity stage. This was the only maturity stage for BM 16 that was significantly different from the check in 1992. In 1993, there was no significant advantage in applying the chemical treatments at the earlier maturity stages. However, all maturity stages resulted in a significantly higher number of suckers per plant than the hand topped check. This was due to the removal of suckers in the top of the check plants at topping.

All chemical treatments except KMH, when averaged across maturities, resulted in an average of fewer than one sucker per plant for either TN 86 or BM 16 in both years. The KMH treatment had a significantly higher number of plants with suckers than any other treatment, regardless of variety or year. The large number of suckers in the KMH treatments was due to the five week interval between chemical application and harvest.

Average Sucker Weight. The maturity stage at which chemical treatments were applied had no effect on sucker weight for TN 86 in 1992 and 1993 (Table 5). Although there were no significant differences, sucker weight increased slightly as chemical treatments were delayed beyond the 25 percent button stage in 1992. This trend was not followed with TN 86 in 1993. The 1992 growing season was not as dry as 1993, resulting in more effective sucker control at the early maturity stages. The delayed application of chemicals likely resulted in some suckers being too large to control. In 1993, chemical sucker control was less effective, which resulted in the development of relatively large suckers in plants that were treated at early maturity.

In 1992 maturity stages for BM 16 were not significantly different. However, sucker weights at all maturity stages were significantly less than that of BM 16 check. In 1993, there were no significant differences in sucker weight among BM 16 maturity stages. Although differences among maturities were quite large, they were not significant because of large variability in sucker weights across reps.
Although the KMH treatment resulted in the highest percentage of plants with suckers and the largest number of suckers per plant, the suckers were smaller than those from

Table 5. Effects of chemical topping treatments and plant maturity stages on average sucker weight for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Avg. Sucker wt.		Leaf	Avg. Sucker wt.	
Treatment[a]	button	1992	1993	number	1992	1993
		g			g	
Check[b]	50	74.6	133.6	30	215.9	103.8
FST7/P+	25	31.8	384.9	25	106.3	260.6
FST7-P+	25	120.2	371.0	25	44.6	349.6
KMH/P+	25	14.7	350.1	25	55.2	237.9
KMH	25	14.3	159.8	25	18.8	32.5
FST7/P+	50	88.6	419.1	30	46.2	58.1
FST7-P+	50	158.9	281.6	30	65.6	102.7
KMH/P+	50	42.9	275.8	30	137.4	123.0
KMH	50	28.2	35.3	30	25.0	23.4
FST7/P+	75	129.3	117.5	35	11.2	156.3
FST7-P+	75	136.5	289.7	35	21.9	116.8
KMH/P+	75	133.8	216.1	35	24.8	136.9
KMH	75	39.9	27.3	35	22.3	131.3
LSD (.05)		102.3	196.8		102.3	196.8
		Means for maturities averaged across treatments				
Check	50	74.6	133.6	30	215.9	103.8
Mean	25	45.2	316.4	25	56.23	220.2
Mean	50	79.6	252.9	30	68.54	76.8
Mean	75	108.6	162.6	35	20.1	135.3
LSD (.05)		103.7	192.7		103.7	192.7
		Means for treatments averaged across maturities				
Check	50	74.6	133.6	30	215.9	103.8
FST7/P+	Mean	81.6	307.1	Mean	54.6	158.3
FST7-P+	Mean	138.5	314.1	Mean	44.0	189.7
KMH/P+	Mean	63.8	280.7	Mean	72.5	165.9
KMH	Mean	27.4	74.1	Mean	22.0	62.4
LSD (.05)		69.9	134.4		69.9	134.4

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.

[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

plants treated with any other chemical treatment. Lower sucker weights for plants treated with KMH were probably due to the mode of action of the chemical treatments. Suckers that are missed during chemical application would not be inhibited by contact or locally systemic sucker control agents. Since KMH is a systemic compound, it would inhibit the growth of these suckers.

For TN 86, the FST7-P+ chemical treatment resulted in a significantly higher sucker weight compared to either KMH/P+ or KMH in 1992. In 1993, the KMH treatment in TN 86 provided sucker weights statistically equal to the check and significantly better than any other treatment. All other chemical treatments requlted in sucker weights significantly higher than the hand topped check. Chemical treatments applied to BM 16 were not different in their effect on sucker weights in 1992 or 1993. However, in 1992 all chemical treatments resulted in significantly lower sucker weights than the hand topped check. This may be due to suckers that were not removed in the check at topping due to the extreme height of the plants (greater than 2 M). Once the top was removed and apical dominance was lost, suckers that were missed during chemical application would become quite large.

EFFECTS OF CHEMICAL TOPPING ON YIELD

Tobacco Yield. Over the two year study, all maturity stages at which chemical treatments were applied to TN 86 resulted in reduced yields in comparison to the hand topped check (Table 6). In 1992 and 1993, treatments applied at the 25 percent button stage resulted in an average significant yield reduction of 455 and 377

Table 6. Effects of chemical topping treatments and plant maturity stages on yield for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Yield		Leaf	Yield	
Treatment[a]	button	1992	1993	number	1992	1993
		kg ha^{-1}			kg ha^{-1}	
Check[b]	50	4104	3341	30	4203	3863
FST7/P+	25	3448	3002	25	4001	3485
FST7-P+	25	3893	3112	25	3741	3463
KMH/P+	25	3659	3001	25	3927	3513
KMH	25	3595	2742	25	3687	3162
FST7/P+	50	3900	3004	30	4067	3836
FST7-P+	50	3986	3206	30	3960	3946
KMH/P+	50	3968	3075	30	4005	3976
KMH	50	3740	3129	30	3959	3432
FST7/P+	75	3926	3246	35	4425	4608
FST7-P+	75	3807	3187	35	4880	4228
KMH/P+	75	3863	2995	35	4940	4454
KMH	75	3818	2948	35	4303	3850
LSD (.05)		401	328		401	328
		Means for maturities averaged across treatments				
Check	50	4104	3341	30	4203	3863
Mean	25	3649	2964	25	3839	3406
Mean	50	3898	3103	30	3997	3798
Mean	75	3871	3094	35	4637	4285
LSD (.05)		409	297		409	297
		Means for treatments averaged across maturities				
Check	50	4104	3341	30	4203	3863
FST7/P+	Mean	3757	3084	Mean	4164	3976
FST7-P+	Mean	3895	3168	Mean	4193	3878
KMH/P+	Mean	3829	3023	Mean	4290	3982
KMH	Mean	3741	2939	Mean	3983	3482
LSD (.05)		373	224		273	224

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.
[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

kg ha^{-1}, respectively. Even though the 25 percent button stage was the most effective for chemical topping and sucker control, it resulted in the lowest yields. Treatments applied at the 50 or 75 percent button stage averaged 222 and 240 kg ha^{-1}, respectively, less than the check over the two year study.

BM 16 produced higher yields as chemical treatments were delayed beyond the 25 leaf stage of maturity in 1992 and 1993. Both the 25 and 30 leaf stage resulted in reduced yields in 1992, in comparison to the hand topped check. However, the 35 leaf stage resulted in yields of 434 kg ha^{-1}, which was significantly higher than the check. There was a significant difference of 798 kg ha^{-1} between the 25 and 35 leaf stage of maturity. Similar trends in yields were noticed for BM 16 in 1993. Yields significantly increased as chemical treatments were delayed beyond the 25 leaf stage. This yield increase is due to an increase in the number of leaves per plant. In comparison to the check, yields were significantly lower when treatments were applied at the 25 leaf stage, and all chemical treatments applied at the 35 leaf stage resulted in significantly higher yields. The BM 16 check that was hand topped was not significantly different in yield from plants that were chemically topped at the 30 leaf stage of maturity.

Over both years, all chemical treatments resulted in reduced yields for TN 86, in comparison to the hand topped check. The KMH treatment resulted in the largest yield reduction and the FST7-P+ sequential treatment resulted in the smallest yield reduction. Although there were no significant differences in yield between chemical treatments in 1992, all treatments significantly decreased yields in 1993, with the exception of FST7-P+. KMH resulted in over 400 kg ha^{-1} yield reduction.

All chemical treatments resulted in lower yields for BM 16 in 1992, with the exception of KMH/P+ tank mix. KMH/P+ resulted in an increase of 87 kg ha^{-1}, in comparison to the hand topped check that yielded 4203 kg ha^{-1}. However, none of the differences were significantly different. In 1993, all chemical treatments except KMH resulted in nonsignificant increases in yield in comparison to the BM 16 check. The KMH treatment caused a significant decrease in yield of at least 381 kg ha^{-1}, compared to all other treatments including the check.

Top Leaf Weight. Applying chemical topping treatments at any maturity stage resulted in a significant reduction, in comparison to the controls, in the weight of the top leaf for both TN 86 and BM 16 (Table 7). The average weight of the top leaf of TN 86 increased as chemical treatments were delayed to the 75 percent button stage of plant maturity. Applying the chemical treatments at the 75 percent button stage as compared to the 25 percent button stage resulted in a significant weight increase of 0.03 kg for the top leaf in 1993. The top leaves of TN 86 were more mature at the 75 percent button stage, resulting in less stunting and distortion from the chemical treatments.

Over the two year study, the weight of the top leaf decreased as chemical treatments were delayed beyond the 25 leaf stage for BM 16. This is due to a larger number of leaves, resulting in smaller top leaves at time of chemical application. Smaller leaves were more susceptible to stunting and distortion due to chemical injury

Table 7. Effects of chemical topping treatments and plant maturity stages on weight of top leaf for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Top leaf weight		Leaf	Top leaf weight	
Treatment[a]	button	1992	1993	number	1992	1993
		kg Plot^{-1}			kg Plot^{-1}	
Check[b]	50	0.22	0.29	30	0.19	0.34
FST7/P+	25	0.16	0.17	25	0.16	0.25
FST7-P+	25	0.13	0.15	25	0.16	0.26
KMH/P+	25	0.12	0.11	25	0.13	0.23
KMH	25	0.13	0.10	25	0.10	0.16
FST7/P+	50	0.15	0.22	30	0.15	0.24
FST7-P+	50	0.16	0.18	30	0.15	0.22
KMH/P+	50	0.16	0.15	30	0.13	0.21
KMH	50	0.14	0.14	30	0.12	0.14
FST7/P+	75	0.15	0.17	35	0.15	0.21
FST7-P+	75	0.18	0.15	35	0.12	0.23
KMH/P+	75	0.17	0.18	35	0.11	0.18
KMH	75	0.14	0.16	35	0.10	0.14
LSD (.05)		0.04	0.04		0.04	0.04
		Means for maturities averaged across treatments				
Check	50	0.22	0.29	30	0.19	0.34
Mean	25	0.13	0.13	25	0.14	0.22
Mean	50	0.15	0.17	30	0.13	0.20
Mean	75	0.16	0.16	35	0.12	0.19
LSD (.05)		0.04	0.03		0.04	0.03
		Means for treatments averaged across maturities				
Check	50	0.22	0.29	30	0.19	0.34
FST7/P+	Mean	0.15	0.19	Mean	0.15	0.23
FST7-P+	Mean	0.16	0.16	Mean	0.14	0.24
KMH/P+	Mean	0.15	0.15	Mean	0.12	0.21
KMH	Mean	0.13	0.13	Mean	0.11	0.15
LSD (.05)		0.03	0.03		0.03	0.03

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.

[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

compared to larger, more mature leaves. The only significant differences in weight of the top leaf among the maturity stages for BM 16 were in 1993. Plants treated at the 25 leaf stage produced a significant increase in the weight of the top leaf, compared to plants treated at the 35 leaf stage of plant maturity.

In comparison to the controls, all chemical treatments resulted in significant reductions in the weight of the top leaf of TN 86 and BM 16. The KMH treatment resulted in the most severe reductions in top leaf weight for TN 86 and BM 16 in both years. TN 86 plants treated with FST7-P+ produced significantly heavier top leaves than plants treated with KMH in 1992. In 1993, all treatments resulted in top leaf weights that were at least 0.10 kg less than the hand topped TN 86 control, which produced 0.29 kg per top leaf. The FST7/P+ treatment resulted in the least reduction in top leaf weight. This treatment, which produced an average weight of 0.19 kg, was significantly better than any of the other chemical treatments. The most severe weight loss, caused by KMH, was 0.06 kg less than the FST7/P+ treatment.

FST7/P+ resulted in the least reduction in weight of the top leaf of BM 16 in 1992, and was significantly better than either KMH/P+ or KMH. KMH gave the largest reduction in top leaf weight, and was significantly lower than all treatments except KMH/P+. In 1993, the KMH treatment resulted in a top leaf weight that was less than half the average weight of the BM 16 check; top leaf weight of KMH was significantly less than any of the other three treatments.

Third Leaf Weight. Reductions in leaf weight were detected down through the third leaf. The effects of chemical topping on the weight of the third leaf were similar to that of the top leaf (Table 8). For TN 86, the application of chemical topping treatments at any maturity stage resulted in significantly reduced weights of the third leaf in comparison to the hand topped control in 1992 and 1993. In 1992 there was at least a 0.04 kg average reduction in the weight of third leaf due to chemical topping in comparison to the check. The average reduction was at least 0.05 kg in 1993. Although the differences were not significant in either year, chemical topping treatments applied at the 75 percent button stage resulted in the least reduction in the weight of the third leaf; the largest weight reductions were observed when treatments were applied at the 25 percent button stage of plant maturity.

Chemical topping treatments resulted in significant reductions in the weight of the third leaf of BM 16 during both years, regardless of the maturity stage at which the chemicals were applied. The only exception was the 35 leaf maturity stage in 1993. In 1992 there was at least a 0.03 kg weight reduction as chemical treatments were applied at later maturity stages. In 1993 there were no significant differences among the plant maturity stages at which the chemical treatments were applied.

Treatment effects for the weight of the third leaf were similar to the treatment effects for weight of the top leaf. All chemical treatments applied to TN 86 resulted in a significant weight reduction, compared to the hand topped check plots, each year. The KMH treatment resulted in the largest weight reduction among the treatments. KMH caused some stunting and distortion in the upper portion of the treated plants. During the two years of the study, third leaf weights for plots treated with KMH were at least 0.03 kg less than all other chemical treatments, and at least 0.07 kg less than

Table 8. Effects of chemical topping treatments and plant maturity stages on weight of third leaf for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	3rd leaf weight		Leaf	3rd leaf weight	
Treatment[a]	button	1992	1993	number	1992	1993
		kg Plot^{-1}			kg Plot^{-1}	
Check[b]	50	0.26	0.27	30	0.26	0.31
FST7/P+	25	0.24	0.22	25	0.28	0.29
FST7-P+	25	0.23	0.21	25	0.26	0.30
KMH/P+	25	0.23	0.21	25	0.22	0.27
KMH	25	0.17	0.16	25	0.15	0.22
FST7/P+	50	0.22	0.22	30	0.16	0.32
FST7-P+	50	0.23	0.23	30	0.19	0.30
KMH/P+	50	0.23	0.21	30	0.16	0.26
KMH	50	0.19	0.18	30	0.14	0.21
FST7/P+	75	0.21	0.24	35	0.18	0.32
FST7-P+	75	0.23	0.21	35	0.17	0.31
KMH/P+	75	0.23	0.21	35	0.14	0.28
KMH	75	0.20	0.21	35	0.13	0.20
LSD (.05)		0.05	0.04		0.05	0.04
		Means for maturities averaged across treatments				
Check	50	0.26	0.27	30	0.26	0.31
Mean	25	0.21	0.20	25	0.23	0.27
Mean	50	0.22	0.21	30	0.20	0.27
Mean	75	0.22	0.22	35	0.16	0.28
LSD (.05)		0.03	0.04		0.03	0.04
		Means for treatments averaged across maturities				
Check	50	0.26	0.27	30	0.26	0.31
FST7/P+	Mean	0.22	0.23	Mean	0.21	0.31
FST7-P+	Mean	0.23	0.22	Mean	0.22	0.30
KMH/P+	Mean	0.23	0.21	Mean	0.19	0.27
KMH	Mean	0.19	0.18	Mean	0.15	0.21
LSD (.05)		0.03	0.03		0.03	0.03

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.

[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

the hand topped check. Other than KMH, none of the other treatments were significantly different from one another.

Chemically treated plots of BM 16 gave similar results. The KMH treatment resulted in a significant reduction in the weight of the third leaf compared to the other treatments during both years. KMH resulted in third leaf weights of 0.11 and 0.10 kg less than the hand topped check in 1992 and 1993, respectively. All chemical topping treatments resulted in significantly lower weights of the third leaf, compared to the hand topped check, in 1992. In 1993, the only chemical treatment other than KMH that resulted in a significant reduction in weight of the third leaf was KMH/P+. FST7/P+ was the best treatment, resulting in leaf weights equal to that of the hand topped check.

Leaf Length. The effects of chemical topping treatments on the length of the top and third leaves are presented in Tables 9 and 10, respectively. The use of chemical topping treatments in TN 86 resulted in significantly shorter leaves during both years, regardless of maturity stage. Although leaf length tended to increase slightly as chemical treatments were delayed to later maturity stages during both years of the study, differences were not significant. In general, chemical treatments applied to BM 16 also resulted in a significant decrease in leaf size during both years, regardless of plant maturity. The only exception was at the 30 leaf stage for length of the top leaf in 1992. Length of the top leaf tended to decrease slightly as chemical treatments were delayed past the 25 leaf stage. With the exception of length of the third leaf in 1993, applying the chemical treatments at the 35 leaf stage resulted in the

Table 9. Effects of chemical topping treatments and plant maturity stages on length of top leaf for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Top leaf length		Leaf	Top leaf length	
Treatment[a]	button	1992	1993	number	1992	1993
		cm			cm	
Check[b]	50	52.5	55.6	30	51.0	61.9
FST7/P+	25	50.3	48.7	25	49.4	56.9
FST7-P+	25	45.8	48.4	25	48.7	59.8
KMH/P+	25	41.1	40.2	25	45.6	52.5
KMH	25	40.8	38.3	25	37.6	45.8
FST7/P+	50	46.0	52.4	30	44.5	56.2
FST7-P+	50	46.4	49.4	30	49.4	55.3
KMH/P+	50	48.5	44.4	30	41.1	50.7
KMH	50	41.5	41.6	30	51.0	43.6
FST7/P+	75	43.8	46.5	35	43.9	53.5
FST7-P+	75	49.8	44.1	35	40.8	52.5
KMH/P+	75	46.6	48.3	35	38.3	47.6
KMH	75	44.7	44.6	35	35.4	44.1
LSD (.05)		5.0	4.1		5.0	4.1
		Means for maturities averaged across treatments				
Check	50	52.5	55.6	30	51.0	61.9
Mean	25	44.5	43.9	25	45.3	53.7
Mean	50	45.6	46.9	30	46.0	51.5
Mean	75	46.2	45.8	35	39.6	49.4
LSD (.05)		5.1	3.7		5.1	3.7
		Means for treatments averaged across maturities				
Check		52.5	55.6	30	51.0	61.9
FST7/P+		46.7	49.2	Mean	47.4	55.5
FST7-P+		47.3	47.3	Mean	46.4	55.9
KMH/P+		45.4	44.3	Mean	42.8	50.3
KMH		42.3	41.5	Mean	38.0	44.5
LSD (.05)		3.4	2.8		3.4	2.8

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.

[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

Table 10. Effects of chemical topping treatments and plant maturity stages on length of third leaf for TN 86 and BM 16 at the Tobacco Experiment Station 1992-1993.

	TN 86			BM 16		
	Percent	3rd leaf length		Leaf	3rd leaf length	
Treatment[a]	button	1992	1993	number	1992	1993
		cm			cm	
Check[b]	50	62.1	59.9	30	61.5	65.5
FST7/P+	25	60.9	58.2	25	63.9	64.2
FST7-P+	25	59.6	57.0	25	62.7	64.5
KMH/P+	25	55.1	53.7	25	57.6	61.2
KMH	25	47.2	46.3	25	45.8	53.3
FST7/P+	50	57.6	59.7	30	56.1	66.5
FST7-P+	50	59.6	58.4	30	61.5	66.9
KMH/P+	50	59.1	57.5	30	58.6	62.0
KMH	50	50.8	50.4	30	50.8	52.3
FST7/P+	75	56.3	59.3	35	50.3	66.9
FST7-P+	75	58.6	52.4	35	49.9	64.4
KMH/P+	75	58.0	56.3	35	44.0	60.7
KMH	75	55.9	51.6	35	41.6	53.5
LSD (.05)		4.5	3.1		4.5	3.1
		Means for maturities averaged across treatments				
Check	50	62.1	59.9	30	61.5	65.5
Mean	25	55.7	53.8	25	57.5	60.8
Mean	50	56.8	56.5	30	56.7	61.9
Mean	75	57.2	54.9	35	46.4	61.4
LSD (.05)		3.8	3.2		3.8	3.2
		Means for treatments averaged across maturities				
Check	50	62.1	59.9	30	61.5	65.5
FST7/P+	Mean	58.3	59.0	Mean	56.7	65.9
FST7-P+	Mean	59.2	55.9	Mean	58.0	65.3
KMH/P+	Mean	57.4	55.8	Mean	53.4	61.3
KMH	Mean	51.3	49.4	Mean	46.1	53.0
LSD (.05)		3.1	2.1		3.1	2.1

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.
[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

shortest leaves. This is due to increased number of leaves, resulting in shorter top leaves.

For TN 86, all chemical topping treatments resulted in a significant reduction in top leaf size in comparison to the hand topped check. All treatments resulted in top leaves that were at least five cm shorter and three cm narrower than the TN 86 check. Reductions in size of the third leaf were not as large. The KMH treatment resulted in the shortest leaves. This is due to an increased number of leaves, resulting in shorter top leaves.

For TN 86, all chemical topping treatments resulted in a significant reduction in top leaf length in comparison to the hand topped check. All treatments resulted in top leaves that were at least five cm shorter than the TN 86 check. Reductions in length of the third leaf were not as large. The KMH treatment resulted in the leaves that were significantly shorter than the other treatments in both years. In 1992 the FST7-P+ treatment resulted in the least reduction in leaf length; in 1993 the FST7/P+ treatment produced the longest leaf.

BM 16 followed similar trends. In general, chemical treatments resulted in significantly shorter leaves. The KMH treatment resulted in the greatest reduction in leaf length in 1992 and 1993. For both years the treatments that included FST7 resulted in the smallest reductions in leaf length, and the treatments that included KMH resulted in the largest reductions in leaf length.

Leaf Width. Data for the widths of the top leaves are presented in Tables 11 and 12. Chemical treatments resulted in decreased width of top leaves in 1992 and

Table 11. Effects of chemical topping treatments and plant maturity stages on width of top leaf for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Top leaf width		Leaf	Top leaf width	
Treatment[a]	button	1992	1993	number	1992	1993
		cm			cm	
Check[b]	50	23.8	28.3	30	22.1	32.8
FST7/P+	25	21.5	21.9	25	22.4	27.4
FST7-P+	25	17.8	21.2	25	20.6	28.0
KMH/P+	25	17.4	18.4	25	20.7	27.7
KMH	25	16.9	17.2	25	14.9	22.9
FST7/P+	50	19.4	25.5	30	18.8	28.8
FST7-P+	50	20.8	22.9	30	20.6	26.6
KMH/P+	50	20.0	21.2	30	16.1	26.4
KMH	50	17.8	19.0	30	22.1	22.9
FST7/P+	75	19.2	22.7	35	20.4	27.8
FST7-P+	75	21.0	22.6	35	17.8	29.2
KMH/P+	75	19.5	25.4	35	17.0	26.8
KMH	75	18.8	22.2	35	16.6	22.2
LSD (.05)		3.0	2.8		3.0	2.8
		Means for maturities averaged across treatments				
Check	50	23.8	28.3	30	22.1	32.8
Mean	25	18.4	19.7	25	19.7	26.5
Mean	50	19.5	22.1	30	19.0	26.2
Mean	75	19.7	23.2	35	17.9	26.5
LSD (.05)		3.2	3.2		3.2	3.2
		Means for treatments averaged across maturities				
Check	50	23.8	28.3	30	22.1	32.8
FST7/P+	Mean	20.0	23.4	Mean	21.2	28.0
FST7-P+	Mean	19.9	22.2	Mean	19.6	27.9
KMH/P+	Mean	19.0	21.6	Mean	18.8	27.0
KMH	Mean	17.8	19.5	Mean	15.9	22.6
LSD (.05)		2.1	1.9		2.1	1.9

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.

[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

Table 12. Effects of chemical topping treatments and plant maturity stages on width of third leaf for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	3rd leaf width		Leaf	3rd leaf width	
Treatment[a]	button	1992	1993	number	1992	1993
		cm			cm	
Check[b]	50	28.2	29.5	30	26.1	33.6
FST7/P+	25	27.3	25.6	25	30.1	30.2
FST7-P+	25	25.6	26.0	25	27.1	31.1
KMH/P+	25	25.0	25.4	25	27.1	31.3
KMH	25	20.9	20.2	25	22.4	27.6
FST7/P+	50	25.4	28.5	30	23.0	33.7
FST7-P+	50	26.9	27.7	30	25.5	35.1
KMH/P+	50	26.4	26.9	30	24.0	31.9
KMH	50	22.3	24.8	30	20.8	29.6
FST7/P+	75	25.0	30.3	35	21.7	34.6
FST7-P+	75	25.0	28.2	35	21.3	34.8
KMH/P+	75	25.2	29.3	35	19.9	33.0
KMH	75	24.1	27.3	35	19.6	29.8
LSD (.05)		2.9	2.0		2.9	2.0
		Means for maturities averaged across treatments				
Check	50	28.2	29.5	30	26.1	33.6
Mean	25	24.7	24.3	25	27.2	30.0
Mean	50	25.3	27.0	30	23.3	32.6
Mean	75	24.8	28.8	35	20.6	33.0
LSD (.05)		2.3	3.6		2.3	3.6
		Means for treatments averaged across maturities				
Check	50	28.2	29.5	30	26.1	33.6
FST7/P+	Mean	25.9	28.1	Mean	24.9	32.9
FST7-P+	Mean	25.8	27.3	Mean	25.3	33.6
KMH/P+	Mean	25.5	27.2	Mean	23.7	32.0
KMH	Mean	22.4	24.1	Mean	20.9	29.0
LSD (.05)		2.0	1.4		2.0	1.4

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.
[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

1993 for both TN 86 and BM 16, regardless of stage of plant maturity at which the chemical treatments were applied. For TN 86, the most severe decrease in leaf width was observed at the 25 percent button stage of plant maturity. This was consistent for both years. The decrease in leaf width was not as severe when chemical treatments were delayed to the 75 percent button stage of plant maturity. The widths of the top leaves ranged from 18.4 cm when treated at the 25 percent button stage to 19.7 cm when chemical application was delayed to the 75 percent stage. Similar trends were observed in 1993.

All of the chemical treatments caused the largest decrease in leaf width when applied at the 25 percent button stage, with the exception of FST7/P+ at the 50 and 75 percent button stage in 1992. The only significant differences in leaf widths among the four chemical treatments applied to TN 86 were with KMH. This was consistent for both years. KMH resulted in significantly narrower leaves than any of the other treatment for both years, with the exception of KMH/P+ in 1992. The chemical treatment that caused the least decrease in leaf width was FST7/P+ both years. However, it still resulted in significantly narrower leaves in comparison to the hand topped check.

Results for BM 16 were similar. All chemical treatments resulted in decreased width of the top leaves, regardless of stage of plant maturity, with the exception of FST7/P+ applied at 25 percent button stage in 1992. For both years, there was no significant difference between any of the maturity stages. However, all maturity stages resulted in leaf widths significantly smaller than the check. In general, the width of the top leaves decreased as chemical treatments were delayed beyond the 25 leaf stage. This is most likely due to the higher number of leaves causing some of the top leaves to be very small at the time of chemical application. This resulted in much more severe stunting of the top leaves.

When averaged across maturity stage, all chemical treatments resulted in decreases in leaf width. Differences in width of the top leaf among the four chemical treatments were small and insignificant, with the exceptions of KMH/P+ in 1992 and KMH for both years. The KMH treatment caused the most severe stunting in the top leaves both years. This was primarily due to the application method and mode of action of KMH.

EFFECTS OF CHEMICAL TOPPING ON QUALITY.

Data for the effects of chemical topping on grade index are presented in Table 13. Both TN 86 and BM 16 had a much lower grade index in 1993 than in 1992. This was likely due to drought stress and low humidity during curing in the 1993 season.

The quality of the TN 86 decreased as chemical treatments were delayed beyond the 25 percent button stage, especially in 1993. In 1992 there were no significant differences among the three maturity stages, even though treatments applied at 25 percent button resulted in the highest quality tobacco. In 1993, the grade index was 61.7 when chemical treatments were applied at 25 percent button; this was significantly higher than the 37.7 average grade index obtained when

Table 13. Effects of chemical topping treatments and plant maturity stages on grade index for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Grade index		Leaf	Grade index	
Treatment[a]	button	1992	1993	number	1992	1993
Check[b]	50	79.2	41.0	30	68.7	38.7
FST7/P+	25	82.1	61.6	25	79.0	42.9
FST7-P+	25	74.8	68.7	25	79.4	41.1
KMH/P+	25	75.6	62.3	25	79.3	37.5
KMH	25	74.4	54.5	25	70.3	38.6
FST7/P+	50	79.2	43.7	30	61.1	36.6
FST7-P+	50	67.6	45.0	30	68.6	44.6
KMH/P+	50	74.8	51.3	30	68.1	37.8
KMH	50	76.3	49.0	30	67.8	38.2
FST7/P+	75	76.3	35.4	35	73.2	41.2
FST7-P+	75	77.4	38.4	35	67.2	34.8
KMH/P+	75	72.4	38.9	35	71.1	38.1
KMH	75	71.9	38.1	35	64.8	35.7
LSD (.05)		10.0	7.20		10.0	7.20
		Means for maturities averaged across treatments				
Check	50	79.2	41.0	30	68.7	38.7
Mean	25	76.7	61.7	25	77.0	40.0
Mean	50	74.5	47.2	30	66.2	39.3
Mean	75	74.5	37.7	35	69.1	37.4
LSD (.05)		6.4	17.2		6.4	17.2
		Means for treatments averaged across maturities				
Check	50	79.2	41.0	30	68.7	38.7
FST7/P+	Mean	75.3	46.9	Mean	70.9	40.2
FST7-P+	Mean	77.1	50.7	Mean	71.7	40.2
KMH/P+	Mean	74.3	50.8	Mean	72.8	37.8
KMH	Mean	74.2	47.2	Mean	67.6	37.5
LSD (.05)		6.8	4.9		6.8	4.9

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.

[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

chemical treatments were applied at 75 percent button. The large variation among maturity stages for grade index was due at least in part to the relative humidity during curing. All of the plots were harvested approximately five weeks after topping. The curing conditions for the later maturity treatments were too hot and dry, resulting in a high percentage of undesirable variegated tobacco.

For BM 16, the grade index decreased as the chemical treatments were delayed from 25 leaves to 35 leaves. Although the differences were not significant, they were consistent for both years. The decrease in grade index associated with delayed stage of plant maturity was due to differing curing conditions and the size of the BM 16 plants. Plants that were allowed to develop 35 leaves were overly large and were damaged during harvesting. The tobacco also overlapped while curing in the barn, which had a detrimental effect on cured leaf quality.

Although chemical treatments applied to TN 86 at the 25 percent button stage of plant maturity resulted in the highest grade index, there were no significant differences among the four chemical treatments for either year. In 1992, FST7-P+ resulted in the highest grade index at 77.1, when averaged across maturity stages. However, KMH/P+ resulted in the highest index, 50.8, in 1993. For BM 16, differences in grade index among the four chemical treatments were relatively small and insignificant in both 1992 and 1993.

CHAPTER V

SUMMARY

The objective of this study was to determine if burley tobacco could be chemically topped using common sucker control materials. The most effective chemical topping for TN 86 for any treatment occurred when applied at the 25 percent button growth stage. Applications at later maturity stages resulted in less effective chemical topping. Chemical treatments applied at later maturity stages were less effective in 1992 than in 1993. For the two year study, the average effectiveness of chemical topping was about 87 percent at the 25 percent button stage of maturity, but only 58 percent if treatment was delayed until 75 percent button. Differences in effectiveness of chemical topping among the four chemical treatments were insignificant. The range was from 71 percent with the FST7-P+ sequential treatment to 77 percent for the KMH/P+ tank mix treatment. Compared to the hand topped check, all the chemical topping treatments resulted in reduced yields. Although the most effective topping was achieved at the 25 percent button maturity stage, application of chemicals at this stage resulted in the largest yield reduction. Over the two year study these yield reductions were near 400 kg/ha, if treatments were applied at the 25 percent button. Applying treatments at 50 and 75 percent button also caused yield reductions, although not as severe. Yields were reduced the most by the KMH treatment, and least by the FST7-P+ sequential treatment. Differences in grade index among the treatments were relatively small.

The yield reductions that occurred with chemical topping were primarily due to reductions in the size of the upper leaves. All of the chemical topping treatments resulted in reduced size of at least the top three leaves, compared to the hand topped checks. The largest reduction in leaf size was observed in plots treated with KMH, and the smallest reductions occurring with the FST7/P+ tank mix treatment. Treatments applied at the 25 percent button stage of maturity caused yield reductions due to decreased leaf size in the top of the plant, and fewer number of leaves. In comparison to the check, treatments applied at the 25 percent button averaged approximately three fewer leaves that were significantly smaller. The size of the top leaf was reduced more than the third leaf from the top, but all the top three leaves were significantly smaller than the check. Treatments applied at the 50 percent button resulted in about the same number of leaves as the checks, but there was a yield reduction due to decreased leaf size in the top of the plant. Treatments applied at the 75 percent button stage resulted in a slight increase in leaf number; however, this was not enough to compensate for the reduction in leaf size.

The most complete sucker control was obtained when chemical treatments were applied at the 25 percent button stage. At the 50 and 75 percent button stage suckers had already began to develop prior to treatment application. The least effective chemical treatment for control of number of suckers was KMH, while the other treatments were relatively effective. This was probably due to the five week time interval between treatment application and harvest, since KMH lost its effectiveness at approximately four weeks. However, the suckers that developed in the KMH treated plots were much smaller than for any of the other treatments.

For BM 16, excellent topping was obtained with all of the chemical treatments, regardless of the stage of maturity at which the treatments were applied. For both years, across all maturity stages, chemical treatments resulted in approximately 99 percent effective chemical topping. In comparison to the hand topped check, yields were significantly reduced by all treatments when applied at the 25 leaf stage of maturity. Yield reductions were much greater for the KMH treatment than any of the other treatments. Except for KMH, all treatments applied at the 30 leaf stage produced yields that were comparable to the check, which was hand topped at 30 leaves. All chemical treatments applied at the 35 leaf stage resulted in significantly increased yields, compared to the check. The KMH/P+ tank mixed treatment resulted in the highest yield and the KMH treatment resulted in the lowest yield.

The size of at least the top three leaves of the plant were reduced, regardless of treatment or time of application. Reduction in leaf size was greatest for the treatments containing KMH. Reductions in leaf size were similar for the FST7-P+ sequential and FST7/P+ tank mix treatments. The reduction in leaf size was more than compensated for by the increased leaf number when treatments were applied at the 35 leaf stage, resulting in yields higher than the check for all chemical treatments.

All chemical treatments provided effective sucker control, regardless of stage of plant maturity, with the exception of KMH. Again, the suckers that did develop in plants treated with KMH were much smaller than those treated with any of the other treatments. KMH's effectiveness for sucker control decreased significantly after the first three weeks.

The results of this research suggest that chemical sucker control compounds can be used to successfully top burley tobacco without adverse effects on yield or quality. However, this appears to be a possibility only if non-flowering varieties are used. One problem with using non-flowering varieties, and compensating for leaf size reduction with increased leaf number is the size of the plants. The 30 and 35 leaf treatments for non-flowering BM 16 were extremely large and heavy. The plots had to be left in the field for at least two days to cure down before they could be handled. Also, to allow for 30 and 35 leaves, the tobacco could not be housed using scaffold wagons; the upper leaves would drag on the ground. Curing problems occurred in the barn due to overlapping of the plants between the barn tiers, which resulted in lower grade indexes for the 30 and 35 leaf treatments. If non-flowering varieties are developed for chemical topping, they would need to have small stalks and relatively short internodes.

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APPENDIX

Table A-1. Effects of chemical topping treatments and plant maturity stages on stalk weight for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Stalk weight plot^{-1}		Leaf	Stalk weight plot^{-1}	
Treatment[a]	button	1992	1993	number	1992	1993
		kg			kg	
Check[b]	50	2.5	1.7	30	3.7	1.9
FST7/P+	25	2.3	0.9	25	2.7	1.5
FST7-P+	25	2.0	1.0	25	2.8	1.3
KMH/P+	25	2.0	0.8	25	3.0	1.4
KMH	25	1.9	0.7	25	2.5	1.1
FST7/P+	50	2.5	1.2	30	4.4	2.0
FST7-P+	50	3.0	1.1	30	3.5	2.2
KMH/P+	50	2.8	1.0	30	3.9	2.2
KMH	50	2.9	1.0	30	3.6	1.8
FST7/P+	75	2.9	3.0	35	5.8	3.3
FST7-P+	75	3.3	2.6	35	6.2	3.7
KMH/P+	75	3.3	2.4	35	6.5	4.2
KMH	75	2.9	2.4	35	5.9	3.0
LSD (.05)		0.7	0.4		0.7	0.4
		Means for maturities averaged across treatments				
Check	50	2.5	1.7	30	3.7	1.9
Mean	25	2.0	0.8	25	2.8	1.3
Mean	50	2.8	1.0	30	3.9	2.0
Mean	75	3.1	2.6	35	6.1	3.5
LSD (.05)		0.6	0.8		0.6	0.8
		Means for treatments averaged across maturities				
Check	50	2.5	1.7	30	3.7	1.9
FST7/P+	Mean	2.6	1.7	Mean	4.3	2.3
FST7-P+	Mean	2.8	1.6	Mean	4.2	2.4
KMH/P+	Mean	2.7	1.4	Mean	4.4	2.6
KMH	Mean	2.5	1.4	Mean	4.0	2.0
LSD (.05)		0.5	0.3		0.5	0.3

[a] FST/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.
[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

Table A-2. Effects of chemical topping treatments and plant maturity stages on width of second leaf for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	2nd leaf width		Leaf	2nd leaf width	
Treatment[a]	button	1992	1993	number	1992	1993
		cm			cm	
Check[b]	50	26.9	29.7	30	24.1	33.1
FST7/P+	25	25.0	25.9	25	26.9	31.2
FST7-P+	25	22.0	25.0	25	26.9	31.9
KMH/P+	25	21.2	23.2	25	23.9	30.5
KMH	25	19.8	18.8	25	18.8	27.0
FST7/P+	50	24.1	27.9	30	21.5	33.4
FST7-P+	50	24.2	27.0	30	23.3	33.5
KMH/P+	50	22.6	25.1	30	21.0	30.2
KMH	50	19.1	22.8	30	18.1	25.9
FST7/P+	75	23.3	26.8	35	21.1	30.7
FST7-P+	75	23.8	25.2	35	19.2	31.3
KMH/P+	75	23.4	27.0	35	18.1	29.3
KMH	75	22.5	23.9	35	18.4	25.5
LSD (.05)		4.4	2.8		4.4	2.8
		Means for maturities averaged across treatments				
Check	50	26.9	29.7	30	24.1	33.1
Mean	25	22.0	23.2	25	24.1	30.1
Mean	50	22.5	25.7	30	21.0	30.8
Mean	75	23.2	25.7	35	19.2	29.2
LSD (.05)		3.3	3.7		3.3	3.7
		Means for treatments averaged across maturities				
Check	50	26.9	29.7	30	24.1	33.1
FST7/P+	Mean	24.1	26.9	Mean	23.2	31.8
FST7-P+	Mean	23.2	25.7	Mean	23.1	32.3
KMH/P+	Mean	22.4	25.1	Mean	21.0	30.0
KMH	Mean	20.4	21.8	Mean	18.4	26.1
LSD (.05)		3.0	1.9		3.0	1.9

[a] FST/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.

[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

Table A-3. Effects of chemical topping treatments and plant maturity stages on stalk length for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Stalk length		Leaf	Stalk length	
Treatment[a]	button	1992	1993	number	1992	1993
		cm			cm	
Check[b]	50	109	111	30	111	106
FST7/P+	25	95	83	25	103	93
FST7-P+	25	95	88	25	102	91
KMH/P+	25	100	76	25	101	91
KMH	25	104	80	25	100	88
FST7/P+	50	108	105	30	126	104
FST7-P+	50	115	101	30	110	113
KMH/P+	50	112	97	30	113	109
KMH	50	117	103	30	115	108
FST7/P+	75	125	137	35	144	131
FST7-P+	75	129	133	35	150	131
KMH/P+	75	125	129	35	151	131
KMH	75	123	129	35	145	130
LSD (.05)		9	10		9.0	10
		Means for maturities averaged across treatments				
Check	50	109	111	30	111	106
Mean	25	98	82	25	101	91
Mean	50	113	102	30	116	108
Mean	75	125	132	35	147	131
LSD (.05)		11	14		11	14
		Means for treatments averaged across maturities				
Check	50	109	111	30	111	106
FST7/P+	Mean	109	108	Mean	124	109
FST7-P+	Mean	113	107	Mean	120	112
KMH/P+	Mean	112	101	Mean	122	110
KMH	Mean	114	104	Mean	120	109
LSD (.05)		6.2	6.8		6.2	6.8

[a] FST/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.
[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

Table A-4. Effects of chemical topping treatments and plant maturity stages on length of second leaf for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	2nd leaf length		Leaf	2md leaf length	
Treatment[a]	button	1992	1993	number	1992	1993
		cm			cm	
Check[b]	50	57.9	56.8	30	55.9	64.6
FST7/P+	25	56.2	55.7	25	57.1	62.0
FST7-P+	25	53.0	54.3	25	58.0	64.9
KMH/P+	25	47.9	49.8	25	52.0	56.7
KMH	25	46.5	42.6	25	41.0	49.1
FST7/P+	50	54.3	56.7	30	52.3	62.7
FST7-P+	50	54.5	54.7	30	56.1	61.7
KMH/P+	50	52.5	52.2	30	51.2	56.8
KMH	50	45.4	45.9	30	45.3	47.2
FST7/P+	75	52.2	50.8	35	46.9	59.4
FST7-P+	75	54.8	48.6	35	43.5	60.5
KMH/P+	75	54.8	51.9	35	39.7	53.0
KMH	75	52.0	46.7	35	39.2	48.4
LSD (.05)		4.7	4.1		4.7	4.1
		Means for maturities averaged across treatments				
Check	50	57.9	56.8	30	55.9	64.6
Mean	25	50.9	50.6	25	52.0	58.2
Mean	50	51.6	52.4	30	51.2	57.1
Mean	75	53.4	49.5	35	42.3	55.3
LSD (.05)		4.2	4.0		4.2	4.0
		Means for treatments averaged across maturities				
Check	50	57.9	56.8	30	55.9	64.6
FST7/P+	Mean	54.2	54.4	Mean	52.1	61.4
FST7-P+	Mean	54.1	52.5	Mean	52.5	62.4
KMH/P+	Mean	51.7	51.3	Mean	47.6	55.5
KMH	Mean	47.9	45.0	Mean	41.8	48.2
LSD (.05)		3.2	2.8		3.2	2.8

[a] FST/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.
[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

Table A-5. Effects of chemical topping treatments and plant maturity stages on second leaf cured weight for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	2nd leaf weight		Leaf	2md leaf weight	
Treatment[a]	button	1992	1993	number	1992	1993
		kg Plot^{-1}			kg Plot^{-1}	
Check[b]	50	0.25	0.28	30	0.24	0.34
FST7/P+	25	0.20	0.21	25	0.22	0.30
FST7-P+	25	0.18	0.20	25	0.23	0.31
KMH/P+	25	0.17	0.19	25	0.17	0.26
KMH	25	0.16	0.13	25	0.12	0.20
FST7/P+	50	0.18	0.24	30	0.16	0.29
FST7-P+	50	0.21	0.23	30	0.19	0.29
KMH/P+	50	0.19	0.20	30	0.16	0.26
KMH	50	0.15	0.17	30	0.14	0.17
FST7/P+	75	0.20	0.21	35	0.16	0.26
FST7-P+	75	0.21	0.18	35	0.14	0.29
KMH/P+	75	0.22	0.21	35	0.12	0.23
KMH	75	0.19	0.18	35	0.12	0.18
LSD (.05)		0.04	0.04		0.04	0.04
		Means for maturities averaged across treatments				
Check	50	0.25	0.28	30	0.24	0.34
Mean	25	0.18	0.18	25	0.18	0.27
Mean	50	0.19	0.21	30	0.16	0.25
Mean	75	0.20	0.20	35	0.14	0.24
LSD (.05)		0.04	0.04		0.04	0.04
		Means for treatments averaged across maturities				
Check	50	0.25	0.28	30	0.24	0.34
FST7/P+	Mean	0.20	0.22	Mean	0.18	0.28
FST7-P+	Mean	0.20	0.20	Mean	0.19	0.30
KMH/P+	Mean	0.19	0.20	Mean	0.15	0.25
KMH	Mean	0.17	0.16	Mean	0.13	0.18
LSD (.05)		0.03	0.03		0.03	0.03

[a] FST/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.

[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

Table A-6. Effects of chemical topping treatments and stage of plant maturity on leaf number for TN 86 and BM 16 at the Tobacco Experiment Station, 1992-1993.

	TN 86			BM 16		
	Percent	Number of leaves		Leaf	Number of leaves	
Treatment[a]	button	1992	1993	number	1992	1993
Check[b]	50	22.6	26.1	30	26.3	29.7
FST7/P+	25	22.9	20.3	25	23.7	28.0
FST7-P+	25	21.3	22.6	25	24.3	26.7
KMH/P+	25	21.7	19.2	25	24.5	26.1
KMH	25	23.0	20.2	25	23.6	26.1
FST7/P+	50	22.8	25.5	30	29.5	29.9
FST7-P+	50	23.0	24.5	30	26.2	31.5
KMH/P+	50	22.6	23.9	30	27.4	29.8
KMH	50	23.3	25.1	30	27.8	29.5
FST7/P+	75	24.4	32.1	35	31.4	35.5
FST7-P+	75	25.3	30.6	35	33.2	35.6
KMH/P+	75	23.8	30.1	35	32.8	35.7
KMH	75	23.6	29.3	35	32.2	26.2
LSD (.05)		2.2	2.8		2.2	2.8
		Means for maturities averaged across treatments				
Check	50	22.6	26.1	30	26.2	29.7
Mean	25	22.2	20.6	25	24.0	26.7
Mean	50	22.9	24.7	30	27.7	30.2
Mean	75	24.2	30.5	35	32.4	35.8
LSD (.05)		2.1	3.9		2.1	3.9
		Means for treatments averaged across maturities				
Check	50	22.6	26.1	30	26.3	29.7
FST7/P+	Mean	23.4	26.0	Mean	28.2	31.1
FST7-P+	Mean	23.2	25.9	Mean	27.9	31.3
KMH/P+	Mean	22.7	24.4	Mean	28.2	30.5
KMH	Mean	23.3	24.8	Mean	27.8	30.6
LSD (.05)		1.5	1.9		1.5	1.9

[a] FST7/P+ = tank mix, FST7-P+ = sequential treatment, KMH/P+ = tank mix.

[b] TN 86 check was hand topped when 50 percent of the plants in the plot row exhibited at least one open flower and BM 16 check was hand topped at 30 leaves; both were treated with KMH/P+.

VITA

Danny Roland Peek was born on June 2, 1969 in Asheville, North Carolina. The author is the son of Dal and Susie Peek of Mars Hill, North Carolina. He began elementary school in August 1975 at Weaverville Elementary in Weaverville, North Carolina. After relocating to Mars Hill during the third grade, he finished elementary school and graduated from Madison High School in Madison County, North Carolina, in June 1987. Danny entered Berea College in Berea, Kentucky, in August 1988 and was awarded the Bachelor of Science degree in Agriculture in May 1992.

Danny accepted a graduate research assistantship at the University of Tennessee at Knoxville in the Plant and Soil Science Department in August 1992. The assistantship was provided by the Philip Morris Tobacco Company. He received the Master of Science degree under the guidance of Dr. Robert D. Miller in December 1995. Danny accepted a position with the North Carolina Cooperative Extension Service in Henderson County, North Carolina, in May 1995.