2023

EFFECTS OF FUNGICIDE PROGRAMS AND LOWER LEAF REMOVAL ON WRAPPER LEAF PRODUCTION IN CONNECTICUT BROADLEAF CIGAR WRAPPER TOBACCO

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Digital Object Identifier: https://doi.org/10.13023/etd.2023.119

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EFFECTS OF FUNGICIDE PROGRAMS AND LOWER LEAF REMOVAL ON WRAPPER LEAF PRODUCTION IN CONNECTICUT BROADLEAF CIGAR WRAPPER TOBACCO

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Agriculture, Food and Environment
at the University of Kentucky

By

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2023

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ABSTRACT OF THESIS

EFFECTS OF FUNGICIDE PROGRAMS AND LOWER LEAF REMOVAL ON WRAPPER LEAF PRODUCTION IN CONNECTICUT BROADLEAF CIGAR WRAPPER TOBACCO

In recent years, there has been increased demand for natural leaf cigar wrappers. Kentucky and Tennessee have been of recent interest as a new area for Connecticut Broadleaf production. Initial production experiences have shown that late-season frogeye leaf spot caused by the pathogen *Cercospora nicotianae* Ellis & Everh. may result in 'green spot' in cured leaf and cause a significant problem for producers of Connecticut Broadleaf cigar wrapper tobacco. Field trials were established in 2021 at Princeton, KY and 2022 in Mayfield, KY and Springfield, TN to evaluate effects of fungicide programs and lower leaf removal on wrapper production and frogeye leaf spot. Flutriafol, copper octanoate, and a program of alternating applications of mancozeb/azoxystrobin/mandipropamid were most effective in increasing yield of wrapper grades and would likely be effective in reducing late-season frogeye leaf spot. In 2021, there were significant reductions in total yield and gross revenue with lower leaf removal treatments. However, there were no significant differences found for wrapper production in 2021 or 2022 at the Kentucky locations. At Springfield in 2022, there were also significant reductions in total yield and gross revenue with lower leaf removal treatments. There were also no significant differences in wrapper production.

KEYWORDS: wrapper production, frogeye leaf spot, Connecticut Broadleaf cigar wrapper tobacco, fungicides, lower leaf removal

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04/28/2023

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ACKNOWLEDGMENTS

There are many people I must thank for making my time at the University of Kentucky possible. First, my advisor Dr. Andy Bailey for the opportunity to be a graduate research assistant starting in 2021. I am grateful for the time that Dr. Bailey has taken to advise me in research and writing. Also, for the opportunity to work as an intern prior to starting as a graduate research assistant. I am thankful for the experiences and knowledge Dr. Bailey has graciously provided over the years. I would also like to thank my committee members, Dr. Bob Pearce and Dr. Kiersten Wise, for their willingness to serve on my committee during my time at the University of Kentucky. I am appreciative of the time and advice they have given me to help further my education and understanding.

Various people have made my research possible other than my committee. Research technicians Chris Rodgers, Vickie Witcher, and intern Miranda Rudolph have assisted in making my project possible. I appreciate all the work that has been done by these individuals over the past two years. Thank you to everyone at the University of Kentucky Research and Education Center for allowing my project to be possible. I also want to thank Andrea Webb for all the advice, research assistance, and knowledge that you shared over the last several years, thank you.

I want to thank my parents, grandparents, and in-laws for the love and support that you have always given me. I appreciate everything that you all have done and continue to do for me. Without your selfless love and sacrifice, none of this would have been possible. A special thank you to Sydney Perkins, my wife, for all the love and support you have given me through this endeavor. I also want to thank all the numerous friends and family that have offered me encouragement, fellowship, and prayers. Thank you all.

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CHAPTER 1. LITERATURE REVIEW

1.1 OVERVIEW OF CONNECTICUT BROADLEAF TOBACCO

The popularity of cigar smoking in the early 1800's increased the demand for a wider tobacco leaf that could be used for cigar binders and wrappers. As a result, the Broadleaf type of tobacco was selected and was commercially produced in 1833 (Anderson, 1952). This new Broadleaf type was predominantly grown in the Connecticut River Valley of Connecticut and Massachusetts, and it became known as Connecticut Broadleaf. Connecticut Broadleaf tobacco was more versatile in use than the Havana and Shade types also grown in the region, which were used predominantly for cigar wrappers. Connecticut Broadleaf is characterized by its drooping leaves that are wider and longer than the other two dominant types that were grown in New England. This allowed Connecticut Broadleaf to be used mostly for cigar binders and wrappers (Anderson, 1952). Connecticut Broadleaf is most similar in growth habit and appearance to dark air-cured tobacco grown in Kentucky. However, it has enhanced leaf quality characteristics that increases its value for cigar production (Bailey and Pearce, 2020). Being a historically important crop for the Connecticut river valley, cigar wrapper has an economic value of approximately $75 million for this region. The value of these crops comes from the production of unblemished high-quality leaves (LaMondia, 2008). In 2017, the Connecticut agricultural census reported there were 882 hectares of this tobacco type grown in Connecticut, producing 1,740,655 kilograms (USDA, NASS). Currently, there are approximately 1,200 hectares of Connecticut Broadleaf tobacco grown in the Connecticut River Valley region, producing approximately 2,700,000 kilograms annually (W.A. Bailey, personal communication).

1.2 CONNECTICUT BROADLEAF IN KENTUCKY

Increased demand for natural leaf cigar wrappers, along with decreased production in the traditional areas of the Connecticut River Valley, has led tobacco dealers to seek new regions for Connecticut Broadleaf production (personal communication, Zach Birchfiel, Hail & Cotton, Inc.). With a long history of tobacco production and recent declines in burley tobacco production, Kentucky and Tennessee have been of recent interest as a potential new area for Connecticut Broadleaf production (Bailey and Pearce, 2019).

The term ‘wrapper’ refers to an excellent quality unblemished leaf, which will be used to wrap the outside of a cigar. Binder refers to the portion of the cigar that is just below the wrapper. The rest of the cigar is comprised of filler, which makes up the center portion of the cigar. Wrapper leaves are graded based on the number of “wrapper cuts” that can be made from a leaf. Wrapper cuts are areas of leaf approximately eight centimeters in width, and 13 centimeters in length. To be considered a wrapper cut, that area of the leaf cannot have any holes, defects, or discoloration. Even the slightest defect can disqualify a wrapper cut (Bailey and Pearce, 2020). There are five grades, or classes, for Connecticut Broadleaf cigar wrapper tobacco. The trash grade would be leaves that cannot produce any wrapper cuts, generally these are the lowest leaves on the plant and have a lot of damage. Trash grade leaves bring $1.32 to $1.76 per kilogram. Filler grade leaves are leaves that can produce at least one wrapper cut on the entire leaf. Filler grade leaves bring $3.31 to $3.86 per kilogram. There are three higher quality grades that are considered “wrapper” grades. The number three wrapper grade, also known as ‘two cut’, are leaves that can produce two wrapper cuts. Two cut leaves bring $6.62 per kilogram.

Number two grade, also known as ‘binder’, are leaves that can produce three to five wrapper cuts. Binder grade leaves bring $9.92 per kilogram. Number one grade, also known as ‘wrapper’, are leaves that can produce six or more wrapper cuts. Wrapper grade leaves bring $15.10 per kilogram (personal communication, Zach Birchfiel, Hail & Cotton, Inc.). When producing Connecticut Broadleaf tobacco, at least 50 percent of the crop needs to fall into these three ‘wrapper’ grades for the crop to be profitable based on current input costs (Bailey and Pearce, 2019). In 2019, there were approximately 1,200 hectares of Connecticut Broadleaf grown in Kentucky and Tennessee (W.A. Bailey, personal communication).

Connecticut Broadleaf requires special care, for there are many variables that can prevent leaves from being wrapper quality. Leaves need to be smooth and thin, so tobacco needs to be harvested when leaves are considered immature by dark tobacco standards. Preventing damage during harvest is critical. Leaves cannot be torn or bruised by rough handling, such as allowing stumps from cut tobacco plants to tear holes in leaves during handling or leaf breakage while spiking plants onto sticks (Bailey et al., 2023). Extra precautions should be given to prevent sunburning as well. Due to the thin nature of the leaves, this type of tobacco can sunburn quickly, so shaded areas or shade cloth needs to be available at the time of harvest. Preventative pest management is also critical for this type of tobacco. Pests such as flea beetles (*Epitrix hiritipennis*), hornworms (*Manduca sexta*), and budworms (*Heliothis virescens*) can create holes in leaves that dramatically reduce quality. Also, fungal and bacterial diseases can cause leaf spots and blotches that will reduce leaf quality as well. Currently, the greatest limitation to growing Connecticut Broadleaf in Kentucky and Tennessee is late season frogeye leaf spot, caused by the pathogen *Cercospora nicotianae* (Stavely & Chaplin, 1972 & Bailey et al., 2023). These infections lead to 'green spot' in the cured leaf, which severely diminishes leaf quality for wrapper grade leaves (Bailey and Pearce, 2021).

1.3 *CERCOSPORA* (FROGEYE LEAF SPOT)

Cercospora species cause leaf spot and blight diseases on various crops (Daub, 1987). These spots generally stay small and separate, but on occasion can coalesce causing leaf blights. The pathogen is spread by conidia produced from dark conidiophores. Conidia are easily spread by wind and/or rain. Once contact is made with a host, conidia germinate and infects through the stomata. The pathogen then colonizes the leaf causing circular spots that are small, brown, and 3-5 millimeters in diameter. Leaf spots will soon become gray, thin, and brittle causing the center to fall out, leaving a rigid hole in the center of the spot (Lucas, 1975). Overwintering of this pathogen occurs as black stromata in old, infected leaves. High temperatures and humidity favor this pathogen, which make it most destructive in the summer months, and in warmer climates. *Cercospora* spores are multicellular conidia. Which are straight to slightly curved, long, slender, dark and/or colorless. *Cercospora* spores require water for germination. Even heavy dew is sufficient to cause infection. The majority of *Cercospora* species produce cercosporin, a toxin that acts as a photosensitizing factor in plant cells. This toxin triggers reactive atomic oxygen production in cells, which disrupts cell membranes causing loss of electrolytes (Agrios, 2005; Daub, 1987).

1.4 CERCOSPORA NICOTIANAE (ELLIS & EVERHART)

Cercospora nicotianae is an endemic pathogen for many types of tobacco. This pathogen causes the disease frogeye leaf spot in tobacco (Ernst & Thiessen, 2020).

Infections usually occur on the lower leaves, and mature leaves are more susceptible than younger leaves (Shew & Lucas, 1991). Infections of tobacco during the earlier stages (before topping) of the growing season generally develop typical frogeye leaf spot symptoms in the field and cured leaf. When infection occurs late in the season (after topping), typical symptoms are not seen in the field but cercosporin prevents the degradation of chlorophyll during curing, leaving distinct green spots while the rest of the leaf cures to brown. Although this green spot phase is not a major quality deterrent in dark air-cured tobacco, it is a major quality problem for cigar wrapper tobacco (Stavely & Chaplin, 1972; Lucas, 1975; Shew & Lucas, 1991).

1.5 *CERCOSPORA NICOTIANAE* IN CONNECTICUT BROADLEAF

In recent years, research and grower experiences have shown that Connecticut Broadleaf grown in Kentucky and Tennessee may be particularly susceptible to late-season *C.nicotianae* infections. Excessive levels of these green spots easily prevent leaves from being graded in the most profitable wrapper or binder categories. These green spots are currently the greatest deterrent to producing economically profitable crops of Connecticut Broadleaf in Kentucky and Tennessee, because in cigar wrapper tobacco, even minor infections are severe (Bailey et. al. 2021; Shew & Lucas, 1991).

Each year, growers experience reduced yield and leaf quality due to diseases, often causing losses in revenue. The best method for controlling diseases is prevention (Shew and Lucas, 1991). Management decisions such as field selection and fungicide use plans should be made well in advance of transplanting. Such practices must be implemented based on field history and sensitivity of diseases. The best prevention method for many diseases is not to plant tobacco in areas where disease problems have occurred in the past.

Areas that are not overly shaded and have adequate air movement can help in prevention of diseases like target spot, frogeye leaf spot, and blue mold. Applications of fungicides can also be a means of disease prevention. Accurate and timely applications are required for the best fungicide performance. Fungicides labeled for tobacco are mostly protectants. These products must be applied before the pathogen arrives to be effective. Applications should be made at recommended intervals when disease pressure is high. The spray volume of applications should increase as the crop increases in size to ensure adequate coverage of the plant. Accurate delivery of fungicides relies on proper calibration of spray equipment. Too little fungicide causes poor disease control, too much fungicide can result in potential injury to the plant, excessive pesticide residues, and unnecessary expense (Johnson et al. 2019).

All fungicides are grouped by the Fungicide Resistance Action Committee (FRAC), which categorizes fungicides by their mode of action. Mode of action refers to the method by which a fungicide either disrupts processes or prevents binding of its targeted pathogen. Fungicides can have different product names, but if the mode of action is the same, fundamentally they affect the pathogen in the same manner. If the same mode of action is repeatedly used, sensitive fungi will be suppressed while resistant fungi are not as affected. This results in more descendants of resistant fungi that creates a shift to a population of fungi that have more resistant individuals to a particular mode of action. Ultimately this can lead to a loss of effectiveness for certain fungicides for controlling diseases in the field. To reduce the chance of resistance development, avoid repeatedly using the same fungicide, or fungicides with the same site of action, or “FRAC Codes”, and alternate fungicides and site of action. Growers are also encouraged to alternate more than two modes of action because there can be potential for a particular fungal population to become resistant to both modes of action. This problem is particularly important if fungicides being used are prone to resistance development. Through using alternate modes of action, the effectiveness of fungicides as a management strategy for disease can be preserved (Pfeufer and Pearce, 2019).

Management strategies need to be developed to help prevent late season *C.nicotianae* infections leading to green spot, in order to enhance wrapper production in Connecticut Broadleaf tobacco. Various fungicides work well in controlling frogeye leaf spot for other crops (Johnson et al. 2019). Testing of these fungicides is needed to evaluate their effects on late season frogeye leafspot control and prevention of green spot in cigar wrapper tobacco.

Lower leaves on tobacco plants are commonly of the lowest quality. Growers have been known to remove these lower leaves after the first side dressing to increase upper stalk grades and yield in flue cured tobacco (Koga & Rukuni, 2017). Leaf purchasers for flue-cured tobacco have been interested in lower-leaf removal programs that will reduce lug grades without negatively impacting yield or profit. Studies showed four and eight leaf removal programs increased leaf and tip grades compared to treatments without leaf removal. However, leaf removal programs reduced total cured leaf yield and value. The reduction in income due to the total yield loss incurred from lower leaf removal showed this management practice may have limited value (Finch et al. 2019). Other studies have been conducted with similar results, with eight leaves removed significantly decreasing yield and value and four leaves removed having minimal impact on yield and value (Edwards, 2005). The effects of removing lower leaves on wrapper leaf production has not been extensively studied in Connecticut Broadleaf tobacco. Also, due to the nature of the *C. nicotianae* pathogen infecting tobacco from the bottom of the plant (Shew & Lucas, 1991), removing the bottom four leaves could play a role in preventing late-season frogeye infection, thus preventing green spot in upper-stalk wrapper leaves.

CHAPTER 2. EVALUATION OF FUNGICIDES TO PREVENT GREEN SPOT AND ENHANCE WRAPPER LEAF PRODUCTION IN CONNECTICUT BROADLEAF TOBACCO

2.1 ABSTRACT

Late-season frogeye leafspot that results in ‘green spot’ in cured leaf has been a significant problem for producers of Connecticut Broadleaf cigar wrapper tobacco in Kentucky and Tennessee. Field trials were established in 2021 at Princeton, KY and 2022 in Mayfield, KY and Springfield, TN to evaluate effects of fungicide programs on frogeye leaf spot. Eleven fungicide programs were evaluated, including nine agrochemicals and two biological based products. In the fungicide trial, applications began three weeks after transplanting and lasted until the final week before harvest. Spray regimens and timings followed product labels. For the Kentucky trials, there was a significant year by treatment interaction. There were significant treatment effects on total yield and gross revenue by year. This year effect was likely due to differences in weather between the two years at the two Kentucky locations. In 2021, there were significant differences for total wrapper grades (sum of two-cut, binder, and wrapper leaves) produced. Flutriafol produced higher wrapper yields than most of the other treatments. Fluopyram also had significantly higher wrapper yield than tobacco treated with fluopicolide, oxathapiprolin, or untreated tobacco. Copper octanoate had higher wrapper yield than the untreated control. There were no significant differences at the Kentucky location in 2022 for total yield, gross revenue, and total wrapper grades. At the Springfield location, there were no significant differences for total yield, total wrapper grades, or gross revenue. Flutriafol, copper octanoate, and the mancozeb/azosystrobin/mandipropamid program were most effective in increasing yield

of wrapper grades in this research and would likely be effective in reducing late-season frogeye leaf spot.

Key words: frogeye leafspot, Connecticut Broadleaf cigar wrapper tobacco, fungicides, gross revenue..

2.2 INTRODUCTION

Currently, the greatest hinderance to profitable Connecticut Broadleaf cigar wrapper production in Kentucky and Tennessee is late season frogeye leafspot, caused by Cercospora nicotianae (Bailey et. al. 2023). With the disease occurring late in the season, typical symptoms are not seen in the field. Cercosporin, a toxin produced by Cercospora, prevents the degradation of chlorophyll during curing, leaving a green spot while the rest of the leaf cures to brown (Stavely & Chaplin, 1972; Daub, 1987). This condition, known as green spot or barn spot, is a major quality problem for cigar wrapper tobacco (Lucas, G., 1975). There are three 'wrapper' grades for this type of tobacco, and at least 50 percent of the crop needs to fall into one of these three 'wrapper' grades for the crop to be profitable based on current input costs (Bailey and Pearce, 2019). The effects of late-season frogeye leaf spot create a challenge for producing leaves that fall into one of the three wrapper grades.

Generally, frogeye lesions are seen as leaf spots that are small and separated. Conidiophores that contain conidia are found in the center of the lesion. Conidia are spread by rain and/or wind, then infect leaf tissue through the stomata. Leaf spots then form and usually are small, brown/gray, and 3-5 millimeters in diameter (Lucas, 1975). This pathogen prefers high humidity and high temperatures, which allows most frogeye leaf spot infections to occur in the summer months. Even heavy morning dews, in summer months, can provide enough moisture for conidia to germinate. After climates are no longer conducive for reproduction, this pathogen overwinters in black stromata, which can be found in old, infected leaf tissue (Agrios, 2005).

Prevention is the best method for managing tobacco diseases (Shew & Lucas, 1991). Fields that have overly shaded areas and do not have adequate air circulation are hot spots for diseases such as frogeye leaf spot. For prevention, areas where tobacco is to be grown need to have adequate air circulation and sunlight. Fungicides should be applied preventatively for frogeye leaf spot management in cigar wrapper tobacco. Previous fungicide research has shown that frogeye leafspot can be managed with a spray program that includes alternating applications of azoxystrobin and mancozeb beginning at three weeks after transplanting (Johnson et al. 2019). However, further research is needed to evaluate the potential of these and other fungicides for control of late-season frogeye leaf spot in cigar wrapper tobacco. The objective of this research was to evaluate several fungicides with various modes of action for control of late-season frogeye leaf spot and enhancement of wrapper grade production in Connecticut Broadleaf cigar wrapper tobacco.

2.3 MATERIALS AND METHODS

2.3.1 Field and Experimental Design Details:

Field trials were conducted at the University of Kentucky Research and Education Center in Princeton, KY in 2021, on a private farm near Mayfield, KY in 2022, and at the University of Tennessee Highland Rim Research & Education Center in Springfield, TN in 2022. The soil types for these locations were Crider silt loam (fine-silty, mixed, active Typic Paleudalfs) at Princeton, Grenada silt loam (Fine-silty, mixed, active, thermic Oxyaquic Fraglossudalfs) near Mayfield, and Sango silt loam (Coarse-silty, siliceous, semiactive, thermic Glossic Fragiudults) at Springfield, TN. (USDA-NRCS, 2023).

Tobacco was transplanted on May 25, 2021, May 14, 2022, and June 1, 2022, respectively. All field management followed current University of Kentucky extension recommendations (Bailey et al., 2023). Plot size at the Kentucky locations in both years was 12 m long and four rows wide, with a row spacing of 101 cm and in-row plant spacing of 81 cm, which gives a plant population of 12,109 plants/ha. At the Springfield, TN location in 2022, plots were 12 m long and four rows wide, with a row spacing of 106 cm and in-row plant spacing of 60 cm, resulting in a plant population of 15,277 plants/ha. All trials in 2021 and 2022 were set up in a randomized complete block design with four replications. The variety used at all locations for both years of testing was a selection of a standard Connecticut Broadleaf variety known as 'C33'[1].

2.3.2 Fungicide Application Details:

Up to six applications of fungicide treatments were applied throughout the growing season in 2021 and 2022. Fungicides tested, number of applications, timings, rates, and spray volumes are listed in Table 1. Application (A) was made approximately three weeks after transplanting. The remaining five spray applications (B, C, D, E, and F) occurred approximately once a week for five weeks following the first application. Spray applications A, B, C, D, E, and F in 2021 and 2022 were made at 140, 140, 234, 374,

[1] 'SPX', Hail and Cotton, Inc., Springfield, TN

374, and 374 L/ha, respectively, using a $C0_2$ -pressurized sprayer. All applications were made using a flat broadcast boom with four nozzles that covered two rows per pass, and a nozzle spacing of 50.8 cm. TX-12 hollow cone nozzles were used for spray applications A, B, and C. TX-18 hollow cone nozzles for spray applications D, E, and F. All four rows of the plot received spray applications, although data was only taken from the center two rows of each plot.

Treatments used for this study had a variety of active ingredients (Table 2). Mancozeb[2] has a FRAC code of M 03 and a mode of action of multi-site contact activity. This product is used for suppression of tobacco diseases such as blue mold (*Peronospora tabacina*), anthracnose (*Colletotrichum gloeosporioides*), sore shin, and target spot (*Rhizoctonia solani*). Azoxystrobin has a FRAC code of 11 and respiration inhibition is its mode of action. It is labeled for tobacco for control of blue mold, frogeye leaf spot, and target spot. Mandipropamid has a FRAC code of 40 and affects cell wall biosynthesis. Mandipropamid is labeled for tobacco for blue mold control. Fluopicolide has a FRAC code of 43, and its mode of action is attacking cytoskeleton and motor protein. It is labeled for tobacco and control of oomycete diseases such as blue mold as well as black shank (*Phytophthora nicotianae*). Oxathiapiprolin is a relatively new product mixture recently registered for tobacco that has a FRAC Code of U15 and its mode of action is attacking lipid synthesis and membrane integrity. Its target foliar disease is blue mold, but also has soil activity against black shank. Copper octanoate has a FRAC code M 01 and has multi-site activity as its mode of action. It is labeled for tobacco for control of blue mold. *Bacillus amyloliquefaciens* strain D747 has a FRAC

[2] For each active ingredient, FRAC codes, modes of action, and target diseases came from product label.

code of P 05, and its mode of action is host plant defense induction. It is labeled for tobacco and for control of angular leaf spot (*Pseudomonas syringae* pv. *tabaci*), anthracnose, brown spot (*Alternaria* spp.), gray mold (*Botrytis cinerea*), powdery mildew (*Erysiphe cichoracearum*), target spot, frogeye leaf spot, and collar rot (*Sclerotinia sclerotiorum*). *Reynoutria sachalinensis* has a FRAC code of BM 02, and it is a biological with multiple modes of action. It is labeled for use in tobacco and its target diseases are blue mold and target spot. Fluopyram has a FRAC code of 7, with respiration inhibition as its mode of action. It is labeled for tobacco and used to suppress nematodes (*Nemathelminthes* spp.). The last three products are not labeled for tobacco but are labeled for control of frogeye leaf spot (*Cercospora sojina*) in soybean, which is also a broadleaf plant. Thiophanate-methyl has a FRAC code of 1, with cytoskeleton and motor protein interference as its mode of action. Flutriafol has a FRAC code of 3 and affects sterol biosynthesis in membranes as its mode of action. Pydiflumetofen + difenoconazole has a FRAC Code of 7 and 3 with a mode of action affecting respiration, and sterol biosynthesis in membranes.

2.3.3 Harvest Details:

The center two rows of the test plots were harvested July 25th of 2022, and July 29th of 2021. After stalk cutting, the tobacco was allowed to field wilt until leaves were pliable enough to withstand spiking. Six plants were spiked onto each stick and evenly spaced on sticks (five sticks per plot). After spiking, plants were loaded onto scaffold wagons and transported to a standard air curing barn. Tobacco was then housed at 30 cm stick spacing on the tier rails and allowed to air cure. Curing barn doors and vents was managed to promote good air-curing conditions regarding relative humidity.

2.3.4 Yield Calculations:

After curing was complete, tobacco was removed from the barns when adequate leaf moisture was present to allow handling and leaf removal without breakage. For each individual plot, tobacco was then stripped of "trash grade" leaves, lower leaves on the stalk torn from handling or otherwise damaged during harvest and obviously contained no wrapper cuts. After trash leaves were removed, stalks were completely stripped of all remaining leaves, and those leaves were graded. Each grade was weighed and yield per hectare was calculated. Yield per hectare was calculated on a plot-by-plot basis by weighing each grade to determine the yield of the plot (Equation 1).

Equation 1. was used to calculate total yield per hectare for each grade. Yield of grade is the total weight of the grade. For total yield per plot, each grade was calculated separately and then totaled. Stalk number is the total number of stalks that were harvested in each plot, row spacing (RS) is the distance between rows in cm, and plant spacing (PS) is the distance between plants in cm within a row.

$$\text{Kg/ha Yield} = \left(\frac{Yield\ of\ Plot\ (kg)}{Stalk\ Number}\right) \mathrm{X} \frac{\left(\frac{10000}{(RS\ x\ PS)}\right)}{1000}$$

2.3.5 Wrapper Grading Specifications:

Wrapper 'cuts' used in grading are approximately eight centimeters in width, and 13 centimeters in length. To be considered a wrapper cut, the leaf area within each cut cannot have any holes, defects, or discoloration. Leaves were removed from the stalk and evaluated to be placed into five grades (trash [$1.32/kg], filler [$3.10/kg], number 3 [$6.62/kg], number 2 [$9.92/kg], and number 1 [$15.10/kg]). Leaves that are placed in the trash grade have no area on the leaf that can produce a wrapper cut. Filler grade leaves are leaves that can produce one wrapper cut. The next three grades are considered 'wrapper' grades. Number 3 grade, also known as "two-cut", are leaves that have two or three wrapper cuts within the leaf. Number 2 grade, also known as "binder", are leaves that have four or five wrapper cuts within the leaf. The last grade is the number 1 grade, also known as "wrapper", this grade is the highest quality and has six or more wrapper cuts within the leaf. Once leaves are graded and separated by grades, each grade is weighed separately.

2.3.6 Fungicide Trial Statistical Analysis:

Data were analyzed using Statistical Analysis Software (SAS) version 9.4 (SAS, 2013). For the fungicide trial in both years, a randomized complete block design analysis was used to determine the effect of fungicide treatments on wrapper leaf production and total yield. Analysis of variance (ANOVA) was used to look for differences in the response variables between the treatments. Response variables included yield for each grade, total yield, gross revenue, and total wrapper yield (sum of two-cut, binder, and wrapper grades). Treatment was considered a fixed effect and rep was considered a random effect. Locations were analyzed separately, and years were analyzed together unless there was a significant interaction between year and treatment. Differences were considered significant when the p-value was less than alpha=0.1. When there were significant differences between the treatments, all pairwise comparisons were made with alpha=0.1.

2.4 RESULTS AND DISCUSSION

Data for each trial (Princeton 2021, Mayfield 2022, Springfield 2022) are presented separately due to treatment by year or treatment by location interactions. ANOVA showed no significant effect of treatment for total yield in either year at the Kentucky locations. Averaged over treatments, there was an effect of year on total yield at the Kentucky locations (p=0.0001), with average total yield of 2,110 kg/ha at Princeton in 2021 and 1,543 kg/ha at Mayfield in 2022 (Table 3). Also, there was no significant effect of treatment for gross revenue at either of the Kentucky locations. However, there was an effect of year on revenue (p=0.0128) when averaged over treatments (Table 3). Average gross revenue across all treatments was $11,693 $/ha in 2021 and $9,368 $/ha in 2022. For total wrapper yield, there were significant differences at Princeton in 2021 (p=0.0719) (Table 4). Tobacco treated with flutriafol had significantly higher wrapper yield than most of the other treatments and produced 760 more kg/ha of wrapper grades than untreated tobacco. Tobacco treated with fluopyram also had significantly higher wrapper yield than tobacco treated with fluopicolide, oxathapiprolin, or untreated tobacco, and tobacco treated with copper octanoate had higher wrapper yield than the untreated control. There were no significant differences in 2022 for total wrapper yield, with wrapper production ranging from 791 to 1,137 kg/ha. ANOVA showed no significant differences for total yield, wrapper yield, or revenue at the Springfield, TN location in 2022 (Table 5). In general, total yield was numerically lowest in untreated tobacco and highest in tobacco treated with oxathiapiprolin or the mancozeb/azoxystrobin/mandipropamid program.

Weather likely contributed to the differences in yield by year for the Kentucky locations (Table 6). In 2021, cumulative rainfall was 45.5 cm over the growing season (May 1 to July 31). In 2022, cumulative rainfall over the same time period was only 19.5 cm. For the month of June in 2022 there was only 2.5 cm of rainfall, compared to 17.25 cm of rainfall in June of 2021. The temperature was also higher in 2022, averaging 23.6^{o} C compared to 22^{o} C in 2021. With higher temperatures and less moisture, there was less disease pressure in 2022. Frogeye leaf spot is highly dependent on the weather. Spores need warm, moist conditions to germinate. In hot, dry environments, there is little effect by the pathogen, due to conditions not being conducive to the pathogen (Lucas, 1975). This would explain the reduction of green spot observed in 2021 and 2022 compared to severity green spot reported in 2019 and 2020 (W.A. Bailey, personal communication). It is thought that heavy rainfall in the final seven to 10 days before harvest may influence late-season *C. nicotianae* infections leading to green spot in cured leaf (W.A. Bailey & B.H. Bluhm, personal communication). There were significant levels of green spot seen in other Connecticut Broadleaf research trials conducted in 2019 and 2020. There was also significantly more rainfall 10 days prior to harvest in 2019 and 2020 than in 2021 and 2022 (Table 7). Rainfall in the 10 days prior to harvest was 4.56 and 4.25 cm in 2019 and 2020, respectively, and 0.43 and 2.25 cm in 2021 and 2022, respectively. Lesser rainfall in the 10 days prior to harvest may have contributed to the reduction of *C. nicotianae* infection and subsequent green spot in 2021 and 2022 compared to what we saw in other Connecticut Broadleaf research in 2019 and 2020.

2.5 CONCLUSION

Weather conditions likely contributed to the lack of treatment effects on total yield and gross revenue at the Kentucky locations in 2021 and 2022.Total average yield and gross revenue were 2110 kg/ha and $11,693 $/ha, respectively, in 2021, and 1,543 kg/ha and $9,368/ha, respectively, in 2022. However, in 2021, tobacco treated with flutriafol yielded higher wrapper grade leaves than most other treatments and produced 760 kg/ha more wrapper grades than untreated tobacco. Copper octanoate was another treatment that yielded higher amounts of wrapper grade leaves compared to untreated tobacco in 2021. With hotter and drier conditions in 2022, total yield was considerably lower than in 2021. Other Connecticut Broadleaf research in 2019 and 2020 had a great deal of green spot and examining weather patterns 10 days before harvest indicated significant rainfall prior to harvest. In 2021 and 2022, there was not substantial rainfall before harvest, and no green spot was found in plots from any treatment. These weather differences, particularly the difference in rainfall in the last 10 days prior to harvest, demonstrates that frogeye leaf spot development may be dependent on heavy, splashing rain just prior to harvest to increase infection on lower leaves. Flutriafol, copper octanoate, and the mancozeb/azosystrobin/mandipropamid program were most effective in increasing yield of wrapper grades in this research and may be effective in reducing late-season frogeye leaf spot due to the timing of the final applications.

Table 1 Fungicide treatments tested and number of applications, application code and timing, rate, and spray volume.

Treatment #	Treatment	Number of Applications	Application Code and Timing (Weeks after Transplant)	Rate	Spray Volume (L/ha)
1	Untreated Control	-	-	-	-
2	Mancozeb	1	A(3)	1.8 g/L	140
	Azoxystrobin	1	B(4)	150 g/ha	140
3	Mancozeb	2	A(3), C(5)	1.79 g/L	140, 234
	Azoxystrobin	2	B(4), D(7)	150 g/ha	140, 374
	Mandipropamid	1	E(8)	150 g/ha	374
4	Fluopicolide	2	D(7), E(8)	140 g/ha	374, 374
5	Oxathiapiprolin	2	D(7), E(8)	30 g/ha	374, 374
6	Copper Octanoate	5	B(4), C(5), D(7), E(8), F(9)	180 g/ha	140, 234, 374, 374, 374
7	*Bacillus Amyloliquefaciens* Strain D747	5	B(4), C(5), D(7), E(8), F(9)	4.68^13 cfu/ha	140, 234, 374, 374, 374
8	*Reynoutria Sachalinensis*	5	B(4), C(5), D(7), E(8), F(9)	460 g/ha	140, 234, 374, 374, 374
9	Fluopyram	2	B(4), C(5)	250 g/ha	140, 234
10	Thiophanate-methyl	4	A(3), B(4), C(5), D(7)	780 g/ha	140, 140, 234, 374
11	Flutriafol	3	B(4), C(5), D(7)	130 g/ha	140, 234, 374
12	Pydiflumetofen+Difenoconazole	3	B(4), C(5), D(7)	200 g/ha	140, 234, 374

Table 2 FRAC codes and modes of action of active ingredients used in fungicide trials on CBT.

Active Ingredient	FRAC Code	Mode of Action
Mancozeb[a]	M 03	multi-site contact activity
Azoxystrobin	11	respiration
Mandipropamid[c]	40	cell wall biosynthesis
Fluopicolide[d]	43	cytoskeleton and motor protein
Oxathiapiprolin[e]	U15	lipid synthesis and membrane integrity
Copper octanoate[f]	M 01	chemicals with multi-site activity
Bacillus amyloliquefaciens strain D747[g]	P 05	host plant defense induction
Reynoutria sachalinensis[h]	BM 02	biological with multiple modes of action
Fluopyram[i]	7	respiration
Thiophanate-methyl[j]	1	cytoskeleton and motor protein
Flutriafol[k]	3	sterol biosynthesis in membranes
Pydiflumetofen+difenoconazole[l]	7, 3	respiration, sterol biosynthesis in membranes

[a]Manzate Pro-Stick, Fungicide, United Phosphorus, Inc., King of Prussia, PA
[b]Quadris, Flowable Fungicide, Syngenta Crop Protection, Inc., Greensboro, NC
[c]Revus, Fungicide, Syngenta Crop Protection, Inc., Greensboro, NC
[d]Presidio, Fungicide, Valent U.S.A, San Ramon, CA
[e]Orondis Ultra A, Fungicide, Syngenta Crop Protection, Inc., Greensboro, NC
[f]Cueva, Flowable Liquid Copper Fungicide, Certis Biologicals, Columbia, MD
[g]Double Nickel LC, BioFungicide, Certis Biologicals, Columbia, MD
[h]Regaila, Biofungicide, Marrone Bio Innovations, Inc., Davis, CA
[i]Velum Prime, Fungicide, Bayer Crop Science, Leverkusen, Germany
[j]Topsin, Wettable Powder, Fungicide, UPL, NA, King of Prussia, PA
[k]Topguard, Fungicide, FMC Corporation, Philadelphia, PA
[l]Miravis Top, Fungicide, Syngenta Crop Protection, Inc., Greensboro, NC

Table 3 Effect of year on average total yield and gross revenue from Princeton, KY (2021) and Mayfield, KY (2022)

Year	Total Yield (kg/ha)[ab]	Gross Revenue ($/ha)[c]
2021	2,110 a	11,693 a
2022	1,543 b	9,368 b
P-value	0.0001	0.0128

[a]Data averaged over fungicide treatment.

[b]Total yield is the sum of trash, filler, and all wrapper grades.

[c]Revenue is total gross revenue and is the sum of the value trash, filler, and all wrapper grades.

Table 4 Effect of fungicide treatment on total wrapper leaf production[a], 2021 (Princeton, KY) and 2022 (Mayfield, KY).

Treatment name	Total Wrapper kg/ha (2021)	Total Wrapper kg/ha (2022)
Untreated Control	788 d	1,113
Mancozeb/Axozystrobin	1,034 bcd	971
Mancozeb/Axozystrobin/Mandipropamid	1,036 bcd	1,068
Fluopicolide	912 cd	953
Oxathiapiprolin	952 cd	1,049
Copper octanoate	1,239 abc	1,126
Bacillus amyloliquefaciens strain D747	1,052 bcd	942
Reynoutria sachalinensis	1,073 bcd	1,052
Fluopyram	1,297 ab	1,137
Thiophanate-methyl	1,167 bc	1,071
Flutriafol	1,548 a	822
Pydiflumetofen + Difenoconazole	1,200 bc	790
P-value	0.0719	0.7038

[a]Total wrapper leaf production is the sum of two-cut (#3 wrapper grade), binder (#2 binder grade), and wrapper (#1 wrapper grade) leaves.

Table 5 Effect of fungicide treatment on total yield, total wrapper yield, and gross revenue, Springfield, TN, 2022.

Treatment Name	Total Yield[a] (kg/ha)	Total Wrapper[b] (kg/ha)	Revenue[c] ($/ha)
Untreated Control	1,967	1,418	11,540
Mancozeb/Axozystrobin	2,073	1,264	11,251
Mancozeb/Axozystrobin/Mandipropamid	2,257	1,401	12,677
Fluopicolide	2,011	1,255	11,079
Oxathiapiprolin	2,208	1,575	13,425
Copper octanoate	2,088	1,316	12,843
Bacillus amyloliquefaciens Strain D747	1,980	1,258	11,883
Reynoutria sachalinensis	2,025	1,355	11,028
Fluopyram	2,077	1,198	11,552
Thiophanate-methyl	2,010	1,292	11,302
Flutriafol	2,164	1,569	12,332
Pydiflumetofen + Difenoconazole	2,144	1,373	11,834
P-value	0.3675	0.1206	0.4260

[a]Total yield is the sum of trash, filler, and all wrapper grades.
[b]Total wrapper yield is summer of wrapper grades (two-cut, binder, and wrapper)
[c]Revenue is total gross revenue and is the sum of the value trash, filler, and all wrapper grades.

Table 6 Weather data[a] at Kentucky locations (Princeton 2021, Mayfield 2022), May 1 to July 31.

Month Year	May 2021	May 2022	June 2021	June 2022	July 2021	July 2022
Highest temp (°C)	31.1	32.5	33.5	35.7	33.1	36.2
Avg High Temp (°C)	23.4	26.3	28.8	30.6	29.6	32.6
Lowest Temp (°C)	3.6	7.2	11.2	9.4	14.6	15.4
Avg Low Temp (°C)	11.7	15.1	18.7	17	19.8	20.2
Avg Mean Temp (°C)	17.5	20.7	23.7	23.8	24.7	26.3
Days above 32°C	0	1	2	11	3	19
Total Precipitation (cm)	10.75	10	17.25	2.5	17.5	7
Days of 0.025 cm or >	12	5	9	1	10	8
Days of 0.25 cm or >	7	5	5	1	7	8
Days of 1.25 cm or >	2	3	4	1	4	2
Days of 2.5 cm or >	1	1	2	1	3	0

[a]Weather data was collected through Kentucky Mesonet at WKU. https://www.kymesonet.org/

Table 7 Precipitation[a] (cm) 10 days prior to harvest for years 2019-2022 at Kentucky locations.

Days prior to harvest	2019 Aug. 5th	2020 Aug. 7th	2021 July 29th	2022 July 25th
1	4.23	0	0	0
2	0.05	0	0	0
3	0	0	0	0
4	0	0.025	0.425	0
5	0	0	0	0
6	0.28	1	0	0
7	0	1.1	0	0
8	0	2	0	2
9	0	0	0	0.25
10	0	0.125	0	0
Total:	4.56	4.25	0.43	2.25

[a]Precipitation data was collected through Kentucky Mesonet at WKU. https://www.kymesonet.org/

CHAPTER 3. EFFECT OF LOWER LEAF REMOVAL ON WRAPPER LEAF PRODUCTION IN CONNECTICUT BROADLEAF TOBACCO

3.1 ABSTRACT

In recent years, there has been increased demand for natural leaf cigar wrappers. The Connecticut River Valley has seen a decrease in production of cigar tobacco, causing tobacco dealers to seek other places to produce Connecticut Broadleaf cigar wrapper tobacco. Kentucky and Tennessee have been of recent interest as a new area for Connecticut Broadleaf production. Late-season frogeye leaf spot that results in ‘green spot’ in cured leaf has been the greatest problem in producing Connecticut Broadleaf cigar wrapper tobacco in Kentucky and Tennessee. As the pathogen splashes from soil and plant debris onto lower leaves of tobacco, removal of lower non-wrapper leaves in the field several weeks prior to harvest may have potential to reduce the disease. Field trials were established in 2021 at Princeton, KY and in 2022 at Mayfield, KY and Springfield, TN to evaluate effects of lower leaf removal on wrapper leaf production. In 2021, a factorial treatment arrangement was used with leaf removal at two levels (four lower leaves removed at topping vs. no leaf removal) and fungicide treatment at two levels (fungicide application vs. no fungicide application). An additional treatment where only the top six to eight leaves were harvested without lower leaf removal or fungicide application was also included in 2021. In 2022, an additional factor of timing of lower leaf removal was included. Treatments in 2022 trials included lower leaf removal at four levels (no leaf removal, leaf removal at layby, or leaf removal at topping, or harvesting only the top eight leaves with no lower leaf removal) and fungicide treatment at two levels (fungicide application vs. no fungicide application). In 2021, there were significant reductions in total yield and gross revenue with lower leaf removal treatments, and even greater total yield reductions where only the top six leaves were harvested with no lower leaf removal. There was also a significant increase in total yield from fungicide application. However, there were no significant differences found for wrapper production in 2021 or 2022 at the Kentucky locations. At Springfield in 2022, there were also significant reductions in total yield and gross revenue with lower leaf removal treatments. Similar to the Kentucky locations in either year, there were no significant differences in wrapper production at the Springfield location in 2022. Based on these data, lower leaf removal programs would not be recommended as a means of increasing wrapper leaf production or revenue in Connecticut Broadleaf cigar wrapper tobacco.

Key words: wrapper production, frogeye leafspot, Connecticut broad leaf cigar wrapper tobacco, lower leaf removal, gross revenue.

3.2 INTRODUCTION

Connecticut Broadleaf is most similar to dark air-cured tobacco grown in Kentucky. However, it has enhanced leaf quality characteristics that increases its value for cigar production (Bailey and Pearce, 2019). In its traditional production area of the Connecticut River Valley in Connecticut and Massachusetts, there has been a decrease in production while there has also been an increased demand for natural leaf cigar wrappers. Therefore, tobacco dealers have been forced to seek other places for production of Connecticut Broadleaf. Kentucky and Tennessee have been of recent interest as a new area for Connecticut Broadleaf production (Bailey and Pearce, 2020).

Wrapper cuts make this crop profitable. The term wrapper refers to an excellent quality leaf that is large enough to fit six to eight wrapper cuts, which will be used to wrap the outside of a cigar. Binder refers to the portion of the cigar that is just below the wrapper. The rest of the cigar is comprised of filler, which makes up the center portion of the cigar. Wrapper cuts are approximately eight cm in width, and 13 cm in length. To be considered a wrapper cut, the leaf area cannot have any holes, defects, or discoloration. Even the slightest defect can disqualify a wrapper cut. There are three wrapper grades for this type of tobacco, and at least 50 percent of the crop needs to fall into these 'wrapper' grades for the crop to be profitable based on current input costs (Bailey and Pearce, 2019).

Currently, the greatest hinderance to growing Connecticut Broadleaf in Kentucky and Tennessee is late-season *C. nicotianae* infections (Bailey et. al. 2023). With these infections occurring late in the season, typical symptoms are not seen. Cercosporin, a toxin produced by *Cercospora*, prevents the removal of chlorophyll during curing, leaving a green spot while the rest of the leaf cures to brown (Stavely & Chaplin, 1972; Daub, 1987). This condition is known as green spot or barn spot and is a major quality problem for cigar wrapper tobacco (Lucas, 1975). The effects of late-season frogeye leaf spot create a challenge for producing leaves that fall into one of the three wrapper grades.

Cercospora nicotianae Ellis & Everh. is the pathogen that causes frogeye leaf spot in tobacco (Ernst & Thiessen, 2020). This pathogen can infect all types of tobacco (Stavely & Chaplin, 1972). For dark and burley tobacco, this pathogen is not as much of a quality concern, but for cigar wrapper where leaf quality is of utmost importance, it is a major problem. Frogeye leaf spot that develops a few days before the tobacco is harvested and put in the barn may result in green spots on the leaves (Lucas, 1975).

Leaf purchasers for flue-cured tobacco have been interested in lower-leaf removal programs that will reduce lug grades without negatively impacting total yield or profit.

Studies have shown four and eight leaf removal programs increased yield of leaf and tip grades compared to treatments without leaf removal. However, leaf removal programs reduced total cured leaf yield and value. The reduction in income due to the total yield loss incurred from lower leaf removal showed this management practice may have limited value (Finch et al. 2019). When growing Connecticut Broadleaf, the effects of removing lower leaves on wrapper leaf production has not been extensively studied. Removal of lower leaves could put more of the plant's energy into upper stalk leaf production and broader upper leaves, which is where most wrapper grade leaves are found. Also, due to the nature of *Cercospora nicotianae* infecting tobacco from the bottom of the plant and moving up the plant, removing the bottom four leaves could play a role in preventing late season *C. nicotianae* infections into upper stalk wrapper leaves, thus preventing green spot in those leaves. The objective of this research was to evaluate the use of lower leaf removal to improve wrapper production and green spot prevention as a management strategy for Connecticut Broadleaf in Kentucky and Tennessee.

3.3 MATERIALS AND METHODS

3.3.1 Field and Experimental Design Details

Field trials were conducted at the University of Kentucky Research and Education Center in Princeton, KY in 2021, and on a private farm near Mayfield, KY, and at the Highland Rim Research & Education Center in Springfield, TN in 2022. The soil types for these locations were Crider silt loam (fine-silty, mixed, active Typic Paleudalfs) at Princeton, Grenada silt loam (Fine-silty, mixed, active, thermic Oxyaquic Fraglossudalfs) near Mayfield, and Sango silt loam (Coarse-silty, siliceous, semiactive, thermic Glossic Fragiudults) at Springfield, TN (USDA-NRCS, 2023). Tobacco was transplanted on May

25, 2021, May 14, 2022, and June 1, 2022, respectively. All field management at all locations followed current University of Kentucky extension recommendations (Bailey et al., 2023). Plot size at the Kentucky locations in both years was 12 m long and four rows wide, with a row spacing of 101 cm and in-row plant spacing of 81 cm, which gives a plant population of 12,109 plants/ha. At the Springfield, TN location in 2022, plots were 12 m long and four rows wide, with a row spacing of 106 cm and in-row plant spacing of 60 cm, resulting in a plant population of 15,277 plants/ha. All trials in 2021 and 2022 were arranged in a randomized complete block design with four replications. The variety used for all locations in both years of testing was a selection of a standard Connecticut Broadleaf variety known as 'C33'[3].

3.3.2 Lower Leaf Trial Application Details

Treatments for the lower leaf removal trial are shown in Table 8. All general production practices followed extension recommendations. The treatment design in 2021 was a two-by-two factorial with lower leaf removal at topping or no lower leaf removal, and fungicide application or no fungicide application. An additional treatment was included in 2021 to evaluate no lower leaf removal and no fungicide with only the top six leaves harvested, leaving the bottom four leaves on the stalk in the field at harvest. The treatment design in 2022 was a four by two factorial with leaf removal at four levels (no lower leaf removal, lower leaf removal at layby [4 wk post-transplant], lower leaf removal or topping [7 wk post-transplant], or harvesting only the top eight leaves on the plant), and fungicide application at two levels (fungicide or no fungicide application).

[3] 'SPX' Hail and Cotton, Inc., Springfield, TN

The lowest four leaves on the bottom of the plant were removed in all treatments that included lower leaf removal.

In 2021, all plants were topped to 10 leaves due to wind damage that caused slight crooks near the top of the plants. Topping to 10 leaves instead of 12 leaves allowed plant stalks to remain straight. Treatments that included lower leaf removal (treatments 3 and 4) had six leaves that were harvested. In treatment five where no lower leaves were removed and only the top of the plant was harvested, the top six leaves were harvested.

In 2022, all plants were topped to 12 leaves. Treatments that included lower leaf removal had eight leaves that were harvested. Where no lower leaves were removed and only the top of the plant was harvested, the top eight leaves were harvested. In treatments that received fungicide applications in either year, azoxystrobin (150 g/ha) was applied at the time of topping, and *Bacillus amyloliquefaciens* strain D747 (4.68^13 cfu/ha) was applied three days prior to harvest. TX-18 hollow cone nozzles were used at 374 L/ha for all fungicide applications in 2021 and 2022.

3.3.3 Harvest Details

The center two rows of all plots were harvested July 29th, 2021 and July 25th, 2022. After cutting, the tobacco was allowed to field wilt until leaves were pliable enough to withstand spiking. Plants were spiked onto sticks at 6 plants per stick, and plants were spaced equally on each stick. After spiking, plants were loaded onto scaffold wagons and transported to a standard air curing barn. Tobacco was then housed at 30 cm stick spacing. Barn vents and doors were managed to optimize curing conditions for air-curing.

3.3.4 Yield Calculations

After air curing was complete, tobacco was removed from the barns when adequate leaf moisture was present to allow handling and leaf removal without breakage. Tobacco was then stripped of "trash grade" leaves, lower leaves on the stalk with ground injury or otherwise damaged from handling during harvest. After trash leaves were removed, stalks were completely stripped, and leaves were graded. Each grade was weighed and yield per hectare was calculated. Yield per hectare was calculated on a plot-by-plot basis by weighing each grade to determine the yield of the plot (Equation 1).

Equation 1. was used to calculate total yield per grade. Yield of grade is the total weight of the grade. Each grade was calculated separately, then totaled. Stalk number is the total number of stalks that were harvested in each plot, row spacing (RS) is the distance between rows in cm, and plant spacing (PS) is the distance between plants in cm within a row.

$$\text{Kg/ha Yield} = \left(\frac{Yield\ of\ Plot\ (kg)}{Stalk\ Number}\right) \text{X} \frac{\left(\frac{10000}{(RS\ x\ PS)}\right)}{1000}$$

3.3.5 Wrapper Grading Specifications

Wrapper 'cuts' used in grading are approximately eight cm in width and 13 cm in length. To be considered a wrapper cut, the leaf area within each cut cannot have any holes, defects, or discoloration. Leaves were removed from the stalk and evaluated to be placed into five grades (trash [$1.32/kg], filler [$3.10/kg], number 3 [$6.62/kg], number 2 [$9.92/kg], and number 1 [$15.10/kg]). Leaves that are placed in the trash grade have no area on the leaf that can produce a wrapper cut. Filler grade leaves are leaves that can produce one wrapper cut. The next three grades are considered 'wrapper' grades. Number 3 grade, also known as "two-cut", are leaves that have two or three wrapper cuts within the leaf. Number 2 grade, also known as "binder", are leaves that have four or five wrapper cuts within the leaf. The last grade is the number 1 grade, also known as "wrapper", this grade is the highest quality and has six or more wrapper cuts within the leaf. Once leaves are graded and separated by grades, each grade is weighed separately for each plot.

3.3.6 Lower Leaf Removal Trial Statistical Analysis

Data were analyzed using Statistical Analysis Software (SAS) version 9.4 (SAS, 2013). For the lower leaf removal trial in both years, a randomized complete block design analysis was used to determine the effect of treatments on wrapper production. Analysis of variance (ANOVA) was used to look for differences in the response variables between the treatments. Response variables included total yield, yield of wrapper grades, and gross revenue. Treatment was considered a fixed effect and rep was considered a random effect. Locations were analyzed separately, and years were analyzed together unless there was an interaction between year and treatment. Differences were considered significant when the p-value was less than alpha=0.1. When there were significant differences between the treatments, all pairwise comparisons were made at alpha=0.1.

3.4 RESULTS AND DISCUSION

ANOVA showed significant reductions in total yield for the lower leaf removal treatments and upper stalk harvest treatment compared to treatments where no lower leaves were removed, and the entire stalk was harvested in 2021 (0.0300) (Table 9). There were also significant differences in total yield between tobacco that received fungicide application and tobacco that did not receive fungicides (0.0707) (Table 10). Also, significant differences between treatments were not found for total yield of wrapper grades for 2021 or 2022 at any location. Treatment had no effect on revenue for either year. However, there was a significant difference in gross revenue between years when averaged over treatments (0.0161) (Table 11). In 2022, no treatment effects were found for any of the response variables at the Mayfield location. For the Springfield location, ANOVA showed a significant reduction in total yield for the lower leaf removal treatments compared to treatments where no lower leaves were removed (0.0208) (Table 12). Lower leaf removal treatments also had significant reductions in gross revenue compared to treatments where no lower leaves were removed (0.0210) (Table 13).

3.5 CONCLUSION

Significant reductions in total yield were seen from lower leaf removal treatments in all locations in both years. There were also no significant increases in wrapper grade yield at any location in either year. There were no differences found for gross revenue between treatments where lower leaves were removed and no lower leaves removed at the Kentucky locations. There was a reduction in gross revenue from the lower leaf removal treatments at the Springfield location. These data suggest that removing lower leaves at either layby or topping decreases total yield, does not increase wrapper production, and may decrease gross revenue. Therefore, based on these results, the practice of removing lower leaves at layby or topping in Connecticut Broadleaf cigar tobacco would not be recommended.

Table 8 Treatments for lower leaf removal trial, 2021 and 2022.

Lower Leaves Removed	Removal Timing	Fungicide Application[c]	Application Timing	Fungicide Rate
None	None	None	-	-
None	None	Azoxystrobin[d] Bacillus amyloliquefaciens strain D747[e]	Topping 3 d-PHI	150 g/ha 4.68^13 cfu/ha
4 Lower Leaves[a]	Layby	None	-	-
4 Lower Leaves[a]	Layby	Azoxystrobin Bacillus amyloliquefaciens strain D747	Topping 3 d-PHI	150 g/ha 4.68^13 cfu/ha
4 Lower Leaves	Topping	None	-	-
4 Lower Leaves	Topping	Azoxystrobin Bacillus amyloliquefaciens strain D747	Topping 3 d-PHI	150 g/ha 4.68^13 cfu/ha
Upper Stalk Harvest (6-8 leaves)[b]	None	None	-	-
Upper Stalk Harvest (6-8 leaves)[ab]	None	Azoxystrobin Bacillus amyloliquefaciens strain D747	Topping 3 d-PHI	150 g/ha 4.68^13 cfu/ha

[a] Treatment not included in 2021 trial.
[b] 2021 trial was topped to 10 leaves with top six leaves harvested. 2022 trial was topped to 12 leaves with top eight leaves harvested.
[c] Fungicide applications were made at a volume of 374 L/ha
[d] Quadris, Flowable Fungicide, Syngenta Crop Protection, Inc., Greensboro, NC
[e] Double Nickel LC, BioFungicide, Certis Biologicals, Columbia, MD

Table 9 Effect of Lower Leaf Removal on Total Yield, UKREC, Princeton, 2021.

Leaf Treatment	Total Yield (kg/ha)[ab]
No Lower Leaves Removed	1,831 a
Lower Leaves Removed at Topping	1,589 b
P-value	0.0300

[a]Data was averaged over fungicide treatments showing main effects of lower leaf removal.
[b]Total yield is the sum of trash, filler, and all wrapper grades.

Table 10 Effect of Fungicide Treatment on Total Yield in Lower Leaf Removal Trial, Princeton, KY, 2021.

Fungicide Treatment	Total Yield (kg/ha)[a]
Fungicide Applied	1,808 a
No Fungicide Applied	1,613 b
P-value	0.0707

[a]Total yield is the sum of trash, filler, and all wrapper grades.

Table 11 Differences in Gross Revenue by Year, Princeton (2021 and Mayfield (2022), KY locations.

Year	Gross Revenue ($/ha)[a]
2021	11,063 a
2022	9,043 b
P-value	0.0161

[a]Revenue is total gross revenue and is the sum of the value trash, filler, and all wrapper grades.

Table 12 Springfield Lower Leaf Removal Treatment on Total Yield

Lower Leaf Removal Treatment	Total Yield (kg/ha)[ab]
No Leaf Removal	1,994 a
Leaf Removal at Layby	1,551 b
Leaf Removal at Topping	1,506 b
P-value	0.0208

[a]Data was averaged over fungicide treatments showing main effects of lower leaf removal.
[b]Total yield is the sum of trash, filler, and all wrapper grades.

Table 13 Main effect of Lower Leaf Removal on Gross Revenue, Springfield TN 2022.

Lower Leaf Removal Treatment	Gross Revenue[ab] ($/ha)
No Leaf Removal	14,375 a
Leaf Removal at Layby	12,337 b
Leaf Removal at Topping	12,317 b
P-value	0.0210

[a]Data was averaged over fungicide treatments showing main effects of lower leaf removal.
[b]Revenue is total gross revenue and is the sum of the value trash, filler, and all wrapper grades.

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