EVALUATION OF FUNGICIDES TO ENHANCE WRAPPER LEAF PRODUCTION IN CONNECTICUT BROADLEAF CIGAR WRAPPER TOBACCO

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Field trials were conducted in 2021 at Princeton KY and in 2022 at Mayfield KY and Springfield TN to evaluate effects of fungicide programs on cigar wrapper leaf production in Connecticut Broadleaf cigar tobacco. Eleven fungicide programs were evaluated, including nine agrochemicals and two biological-based products. Applications began three weeks after transplanting and final applications occurred in the last week before harvest. There were significant treatment by location interactions, likely due to rainfall differences between the Princeton KY 2021 location and both locations in 2022. At Princeton KY in 2021, there were significant differences for total wrapper grades (sum of two-cut, binder, and wrapper leaves) produced. Tobacco treated with flutriafol produced higher wrapper yields than most of the other treatments. Fluopyram-treated tobacco also had significantly higher wrapper yield than tobacco treated with fluopicolide, oxathiapiprolin, or untreated tobacco. Tobacco treated with copper octanoate had higher wrapper yield than untreated tobacco. There were no significant differences in total yield, gross revenue, or total wrapper grades at either location in 2022. Based on 2021 results where significant differences were seen, flutriafol, fluopyram, and copper octanoate were most effective in increasing yield of wrapper grades.

Additional key words: cigar wrapper leaf production, Connecticut Broadleaf cigar wrapper tobacco, fungicides, biological fungicides, gross revenue.

INTRODUCTION

In recent years, there has been increased demand for natural leaf cigar wrappers. At the same time, the Connecticut River Valley has seen a decrease in production of cigar tobacco, causing tobacco dealers to seek other regions for Connecticut Broadleaf cigar wrapper tobacco production. Kentucky and Tennessee have been of recent interest as a new area for Connecticut Broadleaf production, as these states have an existing history of production of cigar wrappers from dark air-cured and dark fire-cured tobacco types. There are three 'wrapper' grades for Connecticut Broadleaf tobacco, and 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 (1, 2). Currently, the greatest hindrance to profitable Connecticut Broadleaf cigar wrapper production in Kentucky and Tennessee is 'green spot' in cured leaf associated with late-season frogeye leafspot infections caused by *Cercospora nicotianae* (3).

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 (2).

Prevention is the best method for managing tobacco diseases (6). Fields that have overly shaded areas and do not have adequate air circulation create conditions that are favorable for diseases such as frogeye leaf spot. For prevention, selecting areas where tobacco is to be grown should consider adequate air circulation and sunlight. Fungicides should be applied preventatively for frogeye leaf spot management in cigar wrapper tobacco to avoid economic penalties associated with reduced wrapper grades. 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 (4). However, foliar applications of azoxystrobin have been shown to cause injury to Connecticut Broadleaf tobacco (3).

Connecticut Broadleaf tobacco requires special care, as there are many variables that can prevent leaves from being wrapper quality. High quality leaves are smooth and thin; thus, tobacco needs to be harvested when leaves are considered immature by other air-cured tobacco type standards. Preventing damage during labor intensive activities, like topping and harvesting, is critical. Leaves cannot be torn or bruised by rough handling, such as allowing stumps from cut tobacco plants to damage leaves during harvest or leaf breakage while placing plants onto sticks to be housed in a curing facility (3). Extra precautions should be given to prevent sunburning as well. Due to the thin nature of the leaves, this type of tobacco can sunburn

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Table 1. 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] Regalia, 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.

quickly, so shaded areas or shade cloth needs to be available at the time of harvest. Also, fungal and bacterial diseases can cause leaf spots and blotches that will reduce leaf quality as well (2). However, the most common leaf spot associated with disease in Connecticut Broadleaf tobacco grown in Kentucky and Tennessee has been ‘green spot’ on cured leaf associated with late-season frogeye leaf spot infections that may show no symptoms prior to harvest. The objective of this research was to evaluate several fungicides with various modes of action for effects on ‘green spot’ of cured leaf and wrapper grade production in Connecticut Broadleaf cigar wrapper tobacco. Wrapper grade leaf production was used to determine effectiveness of fungicides in reduction of ‘green spot’.

MATERIALS AND METHODS

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. (7). Tobacco was transplanted on May 25, 2021, at Princeton, May 14, 2022, at Mayfield, and June 1, 2022, at Springfield. All field management except foliar fungicide application followed current extension recommendations (3). 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 (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 (15,277 plants/ha). All trials were set up in a randomized complete block design with four replications of treatments. The variety used at all locations for both years of testing was a selection of a standard Connecticut Broadleaf variety known as ‘C9’[4], an open-pollinated inbred line (5).

Treatments used for this study had a variety of active ingredients (Table 1) with various modes of action. Mancozeb[5] 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*), as well as 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

[4] ‘SPX’, Hail and Cotton, Inc., Springfield, TN.
[5] For each active ingredient, FRAC codes, modes of action, and target diseases came from product label.

Table 2. 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 of Active Ingredient (ai)	Spray Volume (L/ha)
1	Untreated Control	–	–	–	–
2	Mancozeb	1	A (3)	1.35 g ai/L	140
	Azoxystrobin	1	B (4)	146 g ai/ha	140
3	Mancozeb	2	A (3), C (5)	1.35 g ai/L	140, 234
	Azoxystrobin	2	B (4), D (7)	146 g ai/ha	140, 374
	Mandipropamid	1	E (8)	146 g ai/ha	374
4	Fluopicolide	2	D (7), E (8)	140 g ai/ha	374, 374
5	Oxathiapiprolin	2	D (7), E (8)	35 g ai/ha	374, 374
6	Copper octanoate	5	B (4), C (5), D (7), E (8), F (9)	179 g ai/ha	140, 234, 374, 374, 374
7	*Bacillus Amyloliquefaciens* Strain D747	5	B (4), C (5), D (7), E (8), F(9)	4.74^13 cfu/ha	140, 234, 374, 374, 374
8	*Reynoutria Sachalinensis*	5	B (4), C (5), D (7), E (8), F(9)	22.4 g ai/ha	140, 234, 374, 374, 374
9	Fluopyram	2	B (4), C (5)	249 g ai/ha	140, 234
10	Thiophanate-methyl	4	A (3), B (4), C (5), D (7)	546 g ai/ha	140, 140, 234, 374
11	Flutriafol	3	B (4), C (5), D (7)	128 g ai/ha	140, 234, 374
12	Pydiflumetofen+Difenoconazole	3	B (4), C (5), D (7)	200 g ai/ha	140, 234, 374

for blue mold control. Fluopicolide has a FRAC code of 43, and its mode of action is attacking cytoskeleton and motor proteins. It is labeled for tobacco for 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. It is labeled for tobacco for control of blue mold and a variety of other tobacco diseases. *Bacillus amyloliquefaciens* strain D747 has a FRAC code of P 05, and its mode of action is host plant defense induction. It is labeled for tobacco 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 product 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 tested in this research are not labeled for tobacco but are labeled for control of frogeye leaf spot (*Cercospora sojina*) in soybean. 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, respectively, with mode of actions affecting respiration and sterol biosynthesis in membranes.

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 2. 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, 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.

The center two rows of plots were harvested on July 29, 2021 at Princeton, July 25, 2022 at Mayfield, and August 15, 2022 at Springfield. After stalk cutting, tobacco was allowed to wilt until leaves were pliable enough to withstand placement on sticks. Six plants were put onto each stick and evenly spaced on sticks (five sticks per plot). Sticks were then 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 were managed to promote good air-curing conditions regarding relative humidity.

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, which were 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 and extrapolated for yield per hectare based on the number of plants per plot and plant population used.

Following air curing, leaves were removed from stalks and evaluated to be placed into five grades (trash [$1.32/kg], filler [$3.10/kg], No. 3 wrapper [$6.62/kg], No. 2 wrapper [$9.92/kg], and No. 1 wrapper [$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. No. 3 grade, also known as "two-cut", are leaves that have two or three wrapper cuts within the leaf. No. 2 grade, also known as "binder", are leaves that have four or five wrapper cuts within the leaf. The highest quality grade is the No. 1 grade, also known as "wrapper", this grade has six or more wrapper cuts within the leaf. Once leaves were graded and separated by grades, each grade was weighed separately.

Data were analyzed using Statistical Analysis Software (SAS) version 9.4 (8). 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 evaluate treatment effects. 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 replication was considered a random effect. Locations were analyzed separately. Treatment effects were considered significant when $P < 0.1$. When there were significant differences between treatments, means were separated using Fisher's Protected LSD with $alpha = 0.1$.

RESULTS AND DISCUSSION

Data for each trial (Princeton KY 2021, Mayfield KY 2022, and Springfield TN 2022) are presented separately. ANOVA showed no significant effect of treatment for total yield at either Princeton KY in 2021 or Mayfield KY in 2022. Averaged over treatments, there was an effect of location on total yield between the Princeton KY 2021 and Mayfield KY 2022 locations ($P = 0.0001$), with average total yield of 2,110 kg/ha at Princeton KY in 2021 and 1,543 kg/ha at Mayfield KY in 2022 (data not shown). Major differences seen in total yield between Princeton KY in 2021 and Mayfield KY in 2022 were most likely due to much drier conditions in June and July at Mayfield KY in 2022. The 2021 crop at Princeton KY received 14.75 cm more rainfall in June and 10.5 cm more rainfall in July than the 2022 crop at Mayfield KY (Table 5). Also, there was no significant effect of treatment for gross revenue at Princeton KY in 2021 or Mayfield KY in 2022. However, there was an effect of location on gross revenue ($P = 0.0128$) when averaged over treatments. Average gross revenue across all treatments was $11,693/ha at Princeton KY in 2021 and $9,368/ha at Mayfield KY in 2022 (data not shown). For total wrapper yield, there were significant differences at Princeton KY in 2021 ($P = 0.0719$) (Table 3). 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, oxathiapiprolin, or untreated tobacco, and tobacco treated with copper octanoate had higher wrapper yield than untreated tobacco. There were no significant differences at Mayfield in 2022 for total wrapper yield, with wrapper production ranging from 791 to 1,137 kg/ha (Table 3).

ANOVA showed no significant differences for total yield, wrapper yield, or revenue at the Springfield, TN location in 2022 (Table 4). In general, total yield was numerically lowest in untreated tobacco and highest in tobacco treated with oxathiapiprolin or the mancozeb/

Table 3. Effect of fungicide treatment on total wrapper leaf production[a], 2021 (Princeton, KY) and 2022 (Mayfield, KY).

Treatment Name	Total Wrapper kg/ha (2021)[b]	Total Wrapper kg/ha (2022)
Untreated control	788 d	1,113
Mancozeb/Azoxystrobin	1,034 bcd	971
Mancozeb/Azoxystrobin/ 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.
[b] Means followed by the same letter are not difference according to Fishers Protected LSD at $\alpha = 0.10$.

Table 4. 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/Azoxystrobin	2,073	1,264	11,251
Mancozeb/Azoxystrobin/ 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 leaf production is the sum of two-cut (#3 wrapper grade), binder (#2 binder grade), and wrapper (#1 wrapper grade) leaves.
[c] Revenue is total gross revenue and is the sum of the value of trash, filler, and all wrapper grades.

azoxystrobin/mandipropamid program. Although not statistically different from any other treatment, the highest numerical total wrapper yield, and gross revenue at the Springfield, TN location came from tobacco treated with oxathiapiprolin (Table 4).

Weather likely contributed to the differences in yield between the Princeton KY 2021 and Mayfield KY 2022 locations (Table 5). In 2021, cumulative rainfall was 45.5 cm over the growing season (May 1 to July 31). In 2022, cumulative rainfall over the same 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. Mean temperature was also higher in 2022, averaging 23.6°C compared to 22°C in 2021 for the period of May 1 to July 31. Although rainfall conditions at Springfield TN in 2022 were similar to rainfall conditions in Mayfield KY in 2022 (Table 5), average wrapper production was highest in Springfield, TN in 2022 (1,358 kg/ha compared to 1108 kg/ha in Princeton, KY in 2021 and 1008 kg/ha in Mayfield KY in 2022) when averaged across all treatments.

CONCLUSION

At Princeton KY in 2021, tobacco treated with flutriafol produced more wrapper grades than most other treatments and produced 760 kg/ha more wrapper grades than untreated tobacco. Tobacco treated with fluopyram or copper octanoate also yielded higher amounts of wrapper grade leaves compared to untreated tobacco in 2021. In 2022 at the Mayfield KY location, fluopyram and copper octanoate showed higher wrapper yields than the other treatments. At the Springfield TN location in 2022, oxathiapiprolin and flutriafol also showed higher wrapper yields. However, disease pressure was not high enough at any location to warrant disease control ratings. Since Connecticut Broadleaf tobacco only remains in the field for 65 to 70 days after transplanting, compared to burley and dark tobacco that typically remain in the field for 90 to 100 days, significant infection from diseases that favor mature leaf tissue are uncommon. Based on these results, fungicides that were most effective in increasing yield of wrapper quality Connecticut Broadleaf tobacco were flutriafol, fluopyram, and copper octanoate at Princeton KY in 2021, copper octanoate and fluopyram at Mayfield KY in 2022, and oxathiapiprolin and flutriafol at Springfield TN in 2022. Since no significant diseases were present in these trials to allow disease control evaluation, these results may suggest that these fungicides had other effects on leaf quality. Where diseases are present, management programs for cigar tobacco should involve the use of multiple fungicides with different modes of action to effectively manage diseases while lessening the risk of resistance development.

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Table 5. Weather data at research locations (Princeton 2021, Mayfield 2022, and Springfield 2022).

Location	Princeton[a]			Mayfield[a]			Springfield[b]		
Year	2021			2022			2022		
Month	May	June	July	May	June	July	May	June	July
Highest Temp (C)	31.1	33.5	33.1	32.5	35.7	36.2	32.2	37.2	38.3
Mean High Temp (C)	23.4	28.8	29.6	26.3	30.6	32.6	26.2	31.2	33.6
Mean Temp (C)	17.5	23.7	24.7	20.7	23.8	26.3	20.4	24.6	27.7
Total Precipitation (cm)	10.75	17.25	17.5	10	2.5	7	7	3	11

[a] Weather data was collected from Kentucky Mesonet. https://www.kymesonet.org/
[b] Data collected from research station and reported to weather.gov http://www.weather.gov/wrh/climate?wfo=ohx

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