2021-2022

Burley and Dark Tobacco Production Guide

A cooperative effort of the University of Kentucky, the University of Tennessee, Virginia Tech, and NC State University

University of Kentucky
College of Agriculture, Food and Environment
ID-160

The University of Tennessee
Institute of Agriculture
PB 1782

Virginia Tech
Invent the Future®
436-050

NC STATE UNIVERSITY

Contents

Authors

University of Kentucky

Andy Bailey, Editor
Bob Pearce, Co-Editor

Lowell Bush, J.D. Green, Bob Miller, Edwin Ritchey
Plant and Soil Sciences

Emily Pfeufer
Plant Pathology

Will Snell
Agricultural Economics

Ric Bessin
Entomology

Wayne Sanderson
Biosystems and Agricultural Engineering

Anne Fisher
Kentucky Tobacco Research and Development Center (KTRDC)

University of Tennessee

Neil Rhodes
Plant Sciences

Zachariah Hansen
Entomology and Plant Pathology

Virginia Tech University

David Reed
Crop and Soil Environmental Sciences

Chuck Johnson
Plant Pathology, Physiology, and Weed Science

North Carolina State University

Matthew Vann, Scott Whitley
Crop Science

Hannah Burrack
Entomology

Lindsey Thiessen
Plant Pathology

Cover photo:
Andy Bailey, University of Kentucky, taken at Cundiff Farms, Trigg County, Kentucky.

Introduction

Bob Pearce and Andy Bailey

Burley and dark tobacco growers in the U.S. make hundreds of decisions every growing season that impact the yield and quality of the crops that they produce. These decisions may include choosing appropriate varieties, planning effective pest control measures, or perhaps deciding the best time to top or harvest a crop. Increasingly, tobacco growers are being required by the industry to record and justify their management decisions and actions. The most comprehensive example of this is the U.S. Tobacco Good Agricultural Practices (GAP) program that was initiated during the 2013 growing season and continues annually. In this program, all growers who sell tobacco to GAP Connections member organizations are required to attend training sessions on the principals of GAP and to keep detailed records of their production practices. Growers are currently required to attend training every season in which they plan to sell tobacco. In 2018, GAP Connections introduced the next step in the evolution of the U.S. Tobacco GAP program, GAP Certification. GAP Certification involves more rigorous recordkeeping and auditing requirements that will increase traceability of U.S. tobacco through the production chain and further differentiate U.S. tobacco growers among other tobacco growers around the world. Many GAP Connections member organizations are now requiring growers to become GAP Certified. Additional information about U.S. Tobacco GAP and the GAP Certification program can be found by contacting GAP Connections using the contact information provided below.

The written U.S. Tobacco GAP guidelines often refer growers to "University Tobacco Production Guides" for specific recommendations regarding management decisions. The information and recommendations provided in this guide have been developed and reviewed by tobacco production specialists and scientists at the University of Kentucky, University of Tennessee, Virginia Tech, and North Carolina State University. The purpose of this multi-state guide is to provide all burley and dark tobacco growers with the most up-to-date, research-based recommendations to produce high-yielding, high-quality tobacco. The guide provides advice on industry-accepted practices that may be applied across the burley and dark tobacco growing regions, although in some cases, growers may be referred to their local extension offices for additional information relevant to their specific situation and location.

GAP Connection
2450 E.J. Chapman Drive
Knoxville, TN 37996-001
Office: 865.622.4606
Fax: 865.622.4550
email: info@gapconnections.com
Website: http://www.gapconnections.com/

Competing in a Competitive, Challenging and Changing Marketplace

Will Snell

U.S. tobacco producers face a lot of challenges in today's marketing environment, ranging from declining profitability, labor challenges, changing product demand, and regulatory uncertainty. Consequently, it is vital that producers attempt to gain any competitive advantage they can acquire in combating the challenges from international competitors and a changing/declining marketplace.

Historically, U.S. tobacco producers competed primarily on quality. U.S. tobacco has always been viewed as the best quality tobacco produced in the world, which led to the ability to be competitive in a global market despite its higher prices. However, the U.S. quality advantage has narrowed in recent decades with improved production practices overseas and as tobacco manufacturers have been able to utilize a higher volume of lower quality leaf in their cigarette blends. Plus, quality no longer warrants as large of a price premium in global markets. Alternatively, low quality burley leaf is heavily discounted in both international as well as the domestic market given available lower-price substitutes. Finally, a new generation of tobacco products have been introduced in the marketplace with a different composition of ingredients.

Despite a changing marketplace with a lot of uncertainties, the U.S. dark tobacco sector continues to maintain a relatively strong position given limited competition worldwide, the management skills of existing producers, and the strength of the U.S. smokeless tobacco market. Alternatively, the U.S. burley grower has struggled amidst a marketplace where cigarette consumption continues to decline globally, and where buyers view price as more important than quality in making purchasing decisions.

While price is the single most critical factor in determining competitiveness, today's buying segment is really focusing on "value," which of course includes both price and quality of leaf, but also some intangible factors referred to as social responsibility. Today's tobacco companies are being challenged on many fronts given the health risks associated with their products, demands from stockholders (e.g. eliminating child labor in producing the crop and addressing environment related issues), policymakers enacting tax increases and consumption restrictions, along with the general public's perception of the industry. In response to critics, tobacco companies are attempting (or perhaps being regulated) to be more transparent about the composition, manufacturing and marketing of their products, which directly and indirectly affect growers.

In reality, today's tobacco product marketplace challenge is to manufacture and deliver reduced-risk tobacco products to a declining consumer base amid a critical (and often times divided) public health community and global government bodies calling for increased regulations. This will undoubtedly impact tobacco growers through the demand for their leaf as well as

their production practices, ultimately impacting grower's price, production levels, costs of production, and thus, profitability.

As a result of this changing marketplace, tobacco growers are being called upon to keep better and more detailed records about their production practices. While representing a cost in terms of time and labor, ideally this recordkeeping can become a competitive advantage for U.S. growers if tobacco buyers and ultimately tobacco consumers place value on this activity in reducing health risks and enhancing the social responsibilities of the tobacco companies. If this is the case, multinational tobacco buyers will likely reduce the number of markets they source tobacco from around the globe, and thus provide additional share of marketing opportunities for U.S. growers.

Most farmers value their independence and are reluctant to change. But this highly regulated and demanding tobacco product market will result in changes in the composition and types of tobacco products, which requires closer scrutiny by tobacco companies on how the leaf they purchase is produced. Consequently, future tobacco production will likely continue to be marketed under contractual agreements with more company control over inputs and production practices. Thus, improved communication flow from the company to the grower, and from the grower to the company, outlining clear expectations and outcomes becomes vital.

Based on current economic, political, and regulatory conditions for tobacco, it is not surprising that many current growers remain very concerned about the future. While the type and composition of tobacco products will continue to change in response to changing consumer, policymaker, and regulatory demands, the industry will continue to exist and thus will need tobacco leaf in some form. Presently, the outlook for dark tobaccos is more promising given the smokeless market, but sales of combustible products (i.e., cigarettes) will for the foreseeable future remain a viable and relatively "large," although shrinking, global market requiring both burley and flue-cured tobaccos.

The U.S. tobacco growing sector has observed a loss of more than 90% of the grower base since the tobacco buyout in 2004. Given tightening margins, the product market outlook, increasing share of imported leaf, dilapidating infrastructure, and labor challenges, further concentration will likely occur. While concerning for the tobacco growing sector as a whole, this expected outcome may create additional opportunities for the remaining growers. However, surviving this new tobacco marketing environment will be a challenge.

Intense international competition coupled with concentration in the buying sector suggests limited grower price growth in the future. To survive, U.S. growers must be willing to adapt to a changing product market, produce high quality leaf with reduced health risks, and find ways to constrain the growth or ideally to reduce their cost structure. Improvements in labor efficiency, optimal input usage, and boosting yields will be critical to remain profitable. Consequently, adoption of the recommendations in this production guide will enhance tobacco grower's ability to be profitable and sustainable in the current and foreseeable marketplace.

Selecting Burley Tobacco Varieties

Bob Pearce, Bob Miller, Matthew Vann, and Scott Whitley

Variety selection is important to minimize disease incidence and severity and to suit the growth characteristics desired by individual producers. With contracting the norm for marketing burley tobacco, the needs of the contracting companies must be considered. Growers need to be aware of the wording specific to their contract and be sure to obtain seed that meets the requirements for seed screening. The seed screening process is intended to help reduce the possible accumulation of tobacco-specific nitrosamines (TSNA) during curing and storage of cured tobacco.

Perhaps the most important consideration when choosing a burley tobacco variety is black shank resistance, given the widespread incidence of this disease throughout the burley growing regions in the U.S. At one time, growers were forced to choose between good resistance and the highest potential yields. This is no longer the case, as variety improvements have resulted in resistant varieties with yields comparable to the best yielding black shank-susceptible varieties. The degree of resistance and the specific type of resistance offered by a variety may make a difference, depending on which race of black shank is predominant in a particular field. In fields where black shank has been observed, it is generally best to assume that both races are present and to choose a variety with a good level of resistance to both races, unless it is known that only race 0 is active in those areas.

Table 1 shows the relative survival of selected varieties in nurseries heavily affected by both race 0 and race 1 black shank. Note that year-to-year variation in survival and performance can be quite high. Even highly-resistant varieties can suffer significant losses in years

Table 1. Survival of selected burley tobacco varieties in fields heavily infested with race 0 and race 1 black shank (2017-2019)

	Black Shank % Survival			
Variety	**2017**	**2018**	**2019**	**Mean**
KT 215LC	87	81	93	87
KT 209LC	86	82	82	83
KT 219LC	92	78	79	83
KT 210LC	83	61	78	74
KT 204LC	76	68	67	70
KT 206LC	77	59	47	61
N 7371LC	53	61	48	54
HP 3307PLC	56	44	41	47
TN 90LC	49	32	48	43
NC 7LC	40	38	14	31
KT 212LC	38	25	26	30
HB 4488PLC	35	33	20	29
HB 04PLC	19	8	0	9
N 126LC	17	0	0	6
Hybrid 404LC	10	0	0	3
KY 14 X L8LC	9	0	0	3
Hybrid 403LC	2	0	0	1
Seasonal Avg.	49	39	38	

when weather is conducive to black shank. In most situations, soil-applied fungicides will be necessary to achieve the best results under heavy black shank pressure (see Disease Management, page 33, for best-use guidelines).

In addition to disease resistance, characteristics like handling, stalk diameter, growth habits, yield, and quality are important selection criteria for a variety. Many of the new black shank-resistant varieties are capable of producing high yields (Figure 1, Table 2), and under high rainfall conditions, can produce a large stalk diameter and heavy plants compared to older varieties. Some varieties are said to perform better under stress than others; however, tolerance to drought and excess moisture (wet feet) are difficult to assess, and observations are often skewed by maturity differences at the onset of extreme weather conditions. However, producers must consider that weather patterns change from year to year. Therefore, variety selection should be based mainly on disease history of the site with other characteristics considered secondary.

Table 2. New and Selected[1] Burley Tobacco Varieties - Relative Disease Resistance, Yield Scores, and Maturity.

Variety	Black Shank		Virus Complex[2]	Black Root Rot	Tmv	Fusarium Wilt	Relative Yield Score[2]	Maturity
	Race 0	Race 1						
ms KY 14 X L8LC	10	0	S	M	R	6	8	Early
KT 200LC	6	6	R	H	R	0	8	Late
KT 204LC	7	7	R	H	R	1	8	Med-Late
KT 206LC[5]	10	6	R	H	R	1	8	Med-Late
KT 209LC	10	8	R	H	R	1	8	Med-Late
KT 210LC	10	8	S	H	R	5	8	Late
KT 212LC	10	4	S	H	R	5	6	Early
KT 215LC	10	9	S	H	S	8	8	Late
KT 219LC[3]	10	8	S	H	R	4	7	Early
NC BH 129LC	1	1	S	H	R	1	7	Med-Early
NC 7LC[4]	10	4	R	H	R	5	8	Late
TN 86LC	4	4	R	H	S	0	6	Late
TN 90LC[5]	4	4	R	H	R	0	5	Medium
TN 97LC	4	4	R	H	R	0	6	Med-Late
HYBRID 403LC	0	0	S	M	R	6	9	Medium
HYBRID 404LC	0	0	S[3]	H[3]	R[3]	4	9	Medium
N 126LC	0	0	S	S	R	3	8	Medium
N 777LC	2	2	S	M	S	0	3	Med-Late
N 7371LC	4	4	S	–[6]	–	5	7	Late
NBH 98LC	2	2	S	M	R	3	5	Medium
HB04PLC	0	0	S	H	R	0	7	Med-Early
HB3307PLC	10	5	R	H	S	3	8	Late
HB4488PLC	10	4	R	H	–	3	8	Late
R7-12LC	0	0	S	H	R	4	8	Late

[1] For an extensive list of varieties go to http://www.uky.edu/Ag/Tobacco
[2] Relative yield scores are based on growth under disease-free conditions.
[3] Based on a limited number of field tests and subject to change.
[4] Resistant to root knot nematode (Meloidogyne incognita, Races 1 and 3).
[5] Low resistance to blue mold (Peronospora tabacina).
[6] – Resistance not rated for this disease

In recent years, there has been increasing focus on the production of quality tobacco and how it is affected by variety selection. While quality is somewhat subjective, the grade index does provide a quantifiable measure of leaf quality. The grade index is based on the old federal grading system and assigns a value to each of the grades. A higher grade index indicates higher quality. Some may argue that the federal grading system is outdated, but in recent comparisons, the relative differences in grade index were similar to the difference in quality ratings of major tobacco companies.

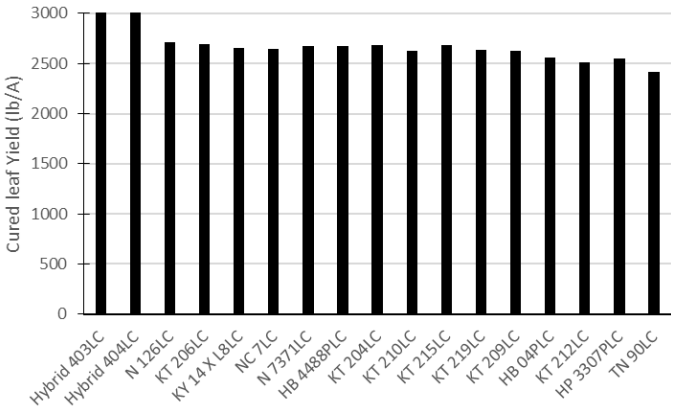


Figure 1. Three-year (2017-2019) average yield of selected burley tobacco varieties grown in the absence of black shank pressure. Varieties are listed in order from highest to lowest yield.

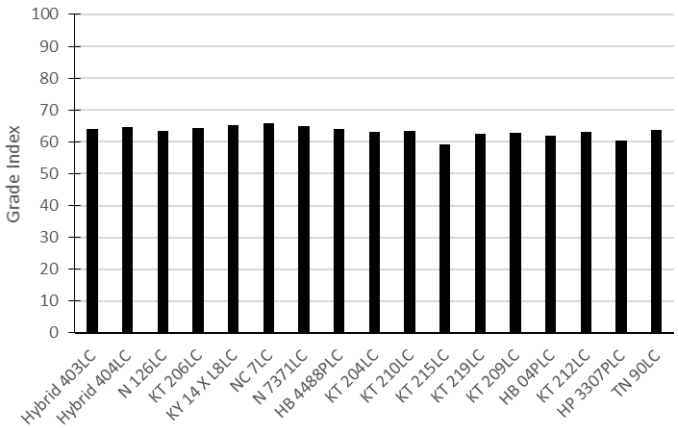


Figure 2. Three-year (2017-2019) of Grade Index for selected burley tobacco varieties. Grade index is a numerical ranking of quality based on the federal grading system, a higher grade index indicates better quality.

While there are some differences in varieties with regard to leaf quality, the differences are typically small (Figure 2) with a range of only about 3 points on the grade index between varieties over three years of testing at four locations. Five varieties (KT 204LC, KT 206LC, TN 90LC, NC 7LC, and KY 14 x L8LC) were compared for grade index across four different studies at each of two locations in Tennessee. The largest difference in leaf quality was observed between curing locations with a range of 29 points on the grade index. The next most important factor in grade index was management, specifically the date of harvest and location of tobacco within the curing barn with a range of 14 points. Variety had the least influence on grade index with an overall range of 2 points between varieties within a particular management and curing location. It should be noted that in these studies, varieties were harvested at the same time and cured under the same conditions. It is well known that curing conditions for burley normally become less favorable in the late fall as opposed to the early fall. To the extent that later maturing varieties will generally be harvested on farms later than early ones, on average they will have less favorable curing conditions. This is especially true for late-maturing varieties planted in mid-to-late June that are not harvested until October, when cool, dry conditions often prevail. It is important to note that the resulting differences in quality are due to harvest date and curing weather, not direct variety differences.

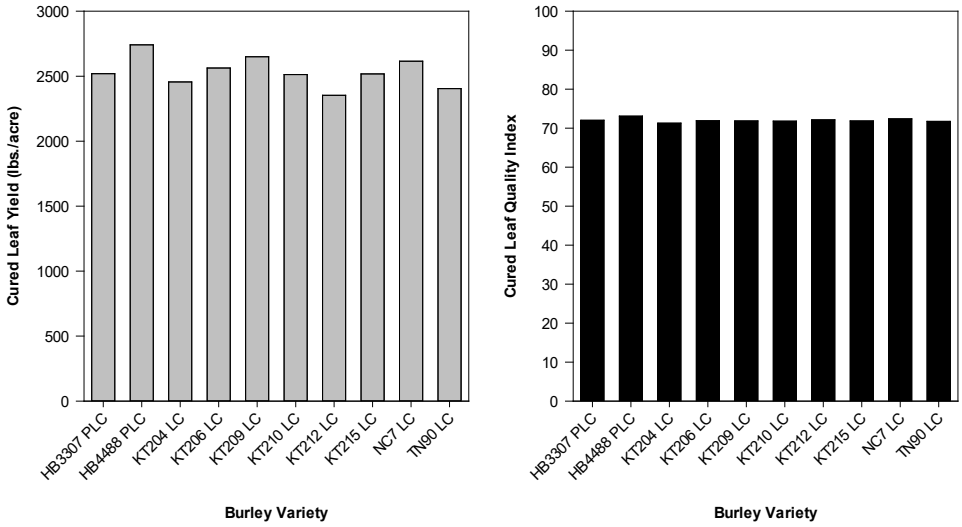


Figure 3. Performance of commercial burley varieties in North Carolina from 2017 – 2019. Data are pooled across six growing environments. Quality is assessed on a 0 – 100 scale, with 100 being the highest quality.

Variety Descriptions

The following are descriptions of the newest and most popular burley tobacco varieties. Information on additional varieties not listed below can be found in Table 3.

KT 219LC is the latest burley tobacco variety released by the Kentucky-Tennessee Tobacco Improvement Initiative (KTTII). It is an early maturing variety that has much higher resistance to black shank in comparison to KT 212LC, which was previously the only early maturing burley variety having resistance to race 1 black shank (Table 1). The level of black shank resistance in KT 219LC is similar to the level of resistance in KT 209LC. KT 219LC has a moderate to high yield potential comparable to ms KY 14 X L8LC. Although the maturity of KT 219LC is not quite as early as ms KY 14 X L8LC, it is similar to KT 212LC, and much earlier than other burley cultivars that have high resistance to race 1 black shank. In most growing seasons, KT 219LC will reach 50% bloom within approximately 60 days following transplanting. Like ms KY 14 X L8LC, KT 219LC produces a relatively short plant that has fewer, but slightly longer leaves, than most other burley cultivars. KT 219LC has a growth habit that is not as droopy as ms KY 14 X L8LC, but it is not as erect as KTTII cultivars other than KT 212LC.

KT 215LC is a late-maturing, high-yielding variety with superior black shank resistance. It has a race 0 resistance of 10 and a race 1 resistance of 9. Note that even though the resistance to black shank is very high in KT 215LC, it is not immune to race 1 (Table 1). In areas with heavy race 1 black shank pressure, fungicides are still recommended for KT 215LC. (see Disease Management, page 33). It also has high resistance to Fusarium wilt and black root rot. It lacks the blue mold tolerance of KT 206LC and has no resistance to tobacco mosaic virus or the virus complex. Yield potential, stalk size, and growth habit are similar to KT 209LC, KT 206LC and KT 204LC. Cured leaf quality has been acceptable, but is slightly lower in comparison to other recently released varieties (Figure 2). Quality issues are primarily seen when KT 215LC is harvested late in the season, so KT 215LC should be planted early enough to allow harvest by mid-September. This variety is recommended for use in fields where black shank and Fusarium wilt occur together. The lack of virus resistance is a concern that should limit widespread general use of this variety.

KT 212LC is an early-maturing, moderate-yielding variety. On a scale of 0 to 10 with 10 being complete resistance, it has a rating of 10 to race 0 black shank and medium resistance (rating of 4) to race 1. Prior to the release of KT 219LC, KT 212LC was the only commercially available variety with early maturity and a significant level of resistance to race 1 black shank. In University variety trials, KT 212LC flowers at about the same time as KY 14 x L8LC. It has high resistance to black root rot, wildfire, and tobacco mosaic virus, but is not resistant to the virus complex. It has medium resistance to Fusarium wilt. Cured leaf quality has been good. This variety will be a good choice for growers who would like to have an early-maturing variety for early harvest, but can't successfully grow KY 14 x L8LC or other early- to medium-maturing varieties because of race 1 black shank. However, it is very important to remember that this variety has only medium resistance to race 1, and will not perform nearly as well as KT 209LC, KT 206LC, or KT 210LC in fields with high race 1 pressure. Much like TN 90LC,

it will perform well in race 1-infested fields only if good rotation practices are followed and soil fungicides are used.

KT 210LC is a late-maturing, high-yielding variety with good black shank resistance and moderate resistance to Fusarium wilt. It has a race 0 resistance of 10 and a race 1 resistance of 7. Fusarium resistance is thought to be about a 5, which is comparable to NC 7LC and KY 14 x L8LC. Fusarium wilt is a soilborne fungal disease that is present in some tobacco-producing regions, primarily along river bottoms. The problem is particularly severe for growers who have both Fusarium wilt and race 1 black shank present in their soils (see Disease Management, page 33). KT 210LC was the first burley variety with moderate-to-high race 1 black shank resistance and moderate Fusarium wilt resistance. It also has high resistance to black root rot, wildfire, and tobacco mosaic virus, but it is susceptible to the virus complex. This variety can get very tall and produce a large number of leaves if topped in mid to late bloom. Topping in the bud or very early bloom stage is recommended for KT 210LC. Cured leaf quality has been good.

KT 209LC is a medium-late-maturing, high-yielding variety with superior black shank resistance. It has a race 0 resistance of 10 and a race 1 resistance of 8. Note that even though the resistance to black shank is relatively high in KT 209LC, it is not immune to race 1 (Table 1). In areas with heavy race 1 black shank pressure, fungicides are still recommended for KT 209LC. (see Disease Management, page 33). It also has high resistance to black root rot, wildfire, tobacco mosaic virus, and tobacco etch virus. It lacks the blue mold tolerance of KT 206LC and has no resistance to Fusarium wilt. Yield potential, stalk size, growth habit, and maturity are similar to KT 206LC and KT 204LC. Cured leaf quality is comparable to TN 90LC.

KT 206LC is a medium-late-maturing variety with high yield potential (Figure 1) and a good overall disease package including good resistance to both races of black shank. It has a 10 level resistance to race 0 of the black shank pathogen and a 7 level resistance to race 1. With most burley growing regions now reporting the presence of race 1 in combination with race 0, KT 206LC performs well in a variety of black shank situations, but not as well as KT 209LC or KT 215LC under the most severe infestations. KT 206LC also has more resistance to blue mold (3 level) than any other black shank resistant variety, but has no resistance to Fusarium wilt and may perform poorly in areas where this disease has become established. This variety can grow quite large and produces a large stalk, making it difficult for some crews to handle at harvest time. Some growers have expressed concern about the cured leaf color of KT 206LC; however, it must be recognized that the two curing seasons following its release were very dry, leading to a situation of quick curing and a tendency for bright-colored leaf regardless of the variety grown. Like any other variety, cured leaf quality of KT 206LC will improve when adequate moisture is available during the curing season. Results from University variety trials show little difference in quality between KT 206LC and other varieties when harvested at the same time and cured under the same conditions (Figure 2, Table 2).

KT 204LC is a medium-late-maturing, high-yielding variety with good black shank resistance. It quickly became a popular variety when it was released in 2004, because it offered improvements in disease resistance and quality compared to older varieties, but it should not be expected to perform as well as KT 209LC or KT 215LC against black shank, especially if race 0 is present in high levels. KT 204LC has no resistance to Fusarium wilt. It is not as tolerant to blue mold as KT 206LC or TN 90LC, but not as susceptible as Hybrid 404LC. KT 204LC tends to grow slowly early in the season, which may discourage producers initially, but its growth in the latter part of the season generally makes up for the slow start. This characteristic can make this variety more susceptible to late season drought.

TN 90LC, a medium-maturing variety with moderately high yield potential, but has dropped in popularity due to increases in the use of the new "KT" varieties. Released in 1990, TN 90LC offers a broad range of important characteristics. TN 90LC became a popular variety due to a good disease resistance package, including moderate resistance to black shank, some tolerance to blue mold, black root rot resistance, and resistance to common virus diseases. TN 90LC still has a small but loyal following due to its agronomic characteristics, including small stalk diameter, upright growth (ease of handling), and good cured-leaf color. Though it does not have the yield potential of some of the new varieties, TN 90LC can produce relatively high yields (Figure 2). Some growers prefer the smaller size and ease of handling with TN 90LC and are willing to accept lower yield potential. In addition to blue mold tolerance, it has level 4 resistance to both races of black shank and high root rot resistance. Its lack of Fusarium wilt resistance is a concern in areas where Fusarium has become widely established.

KY 14 x L8LC continues to decline in popularity due to improvements in new varieties, increased incidence of race 1 black shank, and the extra management required to produce high yields and good quality. It is an early-maturing, short, spreading type of tobacco. Leaves droop to the extent that leaf breakage can be excessive under certain conditions. In addition, leaves appear to be more brittle than most varieties, making KY 14 x L8LC a poor choice for farmers using unskilled laborers for harvest. It has fewer leaves than most varieties, but compensates by producing larger leaves. Stalk diameter is small to medium. Yields are high in fields with no race 1 black shank. Quality can be excellent under proper management. KY 14 x L8LC initiates sucker growth sooner than most other varieties, making early topping a must. Delayed topping increases sucker development and may make sucker control more difficult. Best results are achieved when KY 14 x L8LC is harvested three to four weeks after topping. Delayed harvest may increase sucker control problems and reduce cured leaf quality. KY 14 x L8LC has high resistance to race 0 (10 level) of the black shank pathogen, but no resistance to race 1. The presence of race 1 in many areas has forced producers to abandon KY 14 x L8LC in favor of varieties with resistance to both races. Damage by the virus complex can be severe where virus pressure is high. KY 14 x L8LC may yield poorly if planted in an area with high black root rot pressure. KY 14 x L8LC does have moderate resistance to Fusarium wilt; however, many tobacco growers have realized that KY 14 x L8LC no longer serves their needs as it once did.

HB 04PLC is a variety with high yield potential in fields free of black shank. HB 04PLC is resistant to black root rot and mosaic virus, but has no resistance to black shank. It has medium-early maturity, large leaves, and an average-sized stalk diameter. Cured leaf quality is generally good. It is a good choice

for growers who have no black shank and need a high-yielding variety that matures earlier than the "KT" varieties.

HB 3307PLC, a variety from F.W. Rickard Seed, is a late-maturing variety with a good yield potential and quality. It has high resistance to race 0 black shank and medium resistance to race 1. HB 3307PLC is resistant to black root rot, but has been found to be susceptible to tobacco mosaic virus. Yield potential of this variety is high, but perhaps not quite as high as HB 04PLC or Hybrid 404LC in fields free of black shank. It does not have as large of a stalk and plant size as some of the other new varieties.

HB4488PLC is a late-maturing variety with a high yield potential and quality at least equal to other popular burley varieties. It has high resistance to race 0 black shank and medium resistance to race 1. Field observations indicate a moderately large plant with relatively heavy bodied leaves and a spreading growth habit that is not as upright as "KT" varieties.

Hybrid 404LC, is a medium-maturing variety. It has a high yield potential similar to Hybrid 403LC, but it also has black root rot resistance, making it more suitable than Hybrid 403LC for second-year tobacco or in rotation behind legume crops. Hybrid 404LC does not have black shank resistance or virus complex resistance, so it should only be grown in fields that are known to be free of black shank. It appears to have generally good quality.

N 7371LC, has demonstrated fair resistance to black shank early in the season in some areas, but tests indicate that the resistance does not hold up later in the season. However, this variety will perform well under low black shank pressure. Growers planning to use this variety in fields with a black shank history should plan on also using fungicides. N 7371LC is a very late-maturing variety with a high number of long but narrow leaves and good quality. Topping may be slower than comparable varieties due to the smaller upright leaves in the top of the plant at topping time.

NC 7LC is a late-maturing variety with high resistance to race 0 black shank, and low-to-medium resistance to race 1. Otherwise, NC 7LC has a good disease resistance package, including resistance to black root rot, Fusarium wilt, tobacco mosaic virus, and wildfire. It has a big, robust growth habit with a large stalk diameter. Handling may be difficult under conditions that increase plant size (plant populations under 7,500 plants/A). NC 7 is unique among the burley varieties listed here in that it has resistance to root knot nematode and tobacco cyst nematode. Nematode problems are rare in the U. S. burley growing areas and tend to occur on sandy soils. Yields are expected to be high under ideal conditions, and quality is expected to be good. Avoid areas where race 1 incidence is high. NC 7LC may be a good solution where Fusarium wilt incidence is high. However, if race 1 black shank pressure is also expected to be high, KT 210LC or KT 215LC would be better choices due to higher race 1 resistance.

Selecting Dark Tobacco Varieties

Andy Bailey and Bob Miller

Factors to consider when selecting a dark tobacco variety include resistance to black shank and other diseases, quality, maturity and holdability, and yield potential. Handling characteristics like stalk diameter and growth habit may also be important.

Maturity, holdability after topping, and performance for early and late transplanting are especially important when selecting varieties for double-crop, fire-curing. Growers should adhere to contract specifications for use of LC varieties, and some buyers may even specify or suggest which varieties to use.

Resistance to black shank may be the most important factor for many dark tobacco growers. Although resistance has improved in recent years, most dark tobacco varieties do not have black shank resistance that is comparable to many modern burley varieties. Levels of race 1 black shank continue to increase throughout the dark tobacco region, and varieties with at least some resistance to race 1 black shank should be used in fields where black shank is known to exist. The use of fungicides is also recommended with any dark tobacco variety transplanted into fields with a history of black shank (see Disease Management, page 33, for best-use guidelines). Higher use rates and/or multiple applications are recommended for fields where black shank is known to exist. Consider using burley in fields with significant black shank levels if tobacco must be grown. A four-year rotation with at least one year of a grass crop prior to tobacco is recommended. Dark tobacco should not be grown in the same field for two consecutive years.

Angular leaf spot has become much more common since 2015 in many areas of the dark tobacco production region and may be a larger concern than black shank for some growers. Field trials conducted recently in Tennessee and Kentucky have shown some differences in angular leaf spot susceptibility between dark tobacco varieties. In this edition, we also provide ratings of angular leaf spot susceptibility among dark tobacco varieties.

Agronomic characteristics of dark tobacco varieties may vary between years and locations. Table 1 provides information about specific varieties under normal growing conditions. The following descriptions are based on observations and results from replicated variety trials conducted under different environments across Western Kentucky and Tennessee over the past several years (Tables 2 and 3). Yield potentials listed are an average yield across several trials and seasons, but actual yields may vary. The disease resistance indicated can be expected if disease pressure is present.

Variety Descriptions

DF 911 is a minor fire-cured variety but may also work relatively well as an air-cured variety. It has medium maturity and excellent yield potential (3,300 lb/A). DF 911 has a prostrate growth habit somewhat similar to the Madoles but has a larger stalk size than most other dark tobacco varieties. Cured leaf quality is typically lower than most other varieties, as the leaf face tends to cure to a dark brown, while the back of the leaf cures to a light tan. DF 911 has high resistance to black root rot, wildfire, and tobacco mosaic virus.

DT 538LC is typically used as a fire-cured variety but may also be air-cured. It has excellent yield (3,300 lb/A) but fair cured leaf quality. It has race 0 and race 1 black shank resistance slightly higher than KT D8LC, medium resistance to black root rot, and is less susceptible to angular leaf spot. DT 538LC has medium maturity with a semi-erect growth habit and fairly coarse leaf texture.

DT 558LC is typically used as a fire-cured variety but may also be air-cured. DT 558LC is very similar to DT 538LC in maturity and plant growth characteristics. It has similar yield characteristics (3,200 lb/A) with similar cured leaf quality to DT 538LC when fire cured. It may have better leaf quality than DT 538LC when air cured. Similar to DT 538LC, DT 558LC has medium resistance to black shank race 0 and race 1 as well as medium resistance to black root rot.

KT D14LC has good resistance to both races of black shank, with level 10 resistance to race 0 and level 5 resistance to race 1 black shank. It also has high resistance black root rot, tobacco mosaic virus, and wildfire. It performs relatively well as both a fire-cured or air-cured variety, but like all KTTII varieties, it has inferior air-cured quality in comparison to older non-black shank resistant varieties such as Little Crittenden and NL Madole. It has medium maturity with good yield characteristics. In direct field comparisons, KT 14LC has not performed as well as the recently released KT D17LC, so growers who have previously used KT D14LC for the control of black shank may want to consider trying KTD 17LC as an alternative.

Table 1. Characteristics of dark tobacco varieties.

Variety	Maturity	Black Shank (0-10)[a]		Use[b]	Relative Yield Score[c]	Relative Quality Score[c]	Black Root Rot[de]	TMV	Wildfire	Angular leaf spot[f]
		Race 0	Race 1							
NL Mad LC	Med-Late	0	0	F/A	7	9	S	S	S	S
TR Madole	Early-Med	0	0	F	6	6	S	S	S	S
Lit Crit	Med-Late	0	0	A/F	5	9	S	S	S	LS
KY 160	Medium	0	0	A	3	9	S	R	S	-
KY 171[f]	Medium	0	0	A/F	7	7	R	R	S	S
DF 911	Medium	0	0	F	8	6	R	R	R	-
VA 309	Early-Med	2	2	A/F	6	7	S	S	-	S
VA 359	Medium	1	1	A/F	6	7	S	S	-	-
TN D950	Early	3	3	F	8	6	R	R	R	HS
KT D6LC	Early-Med	3	3	F	8	7	R	R	R	S
KT D8LC	Medium	4	4	F/A	9	5	S	S	S	S
KT D14LC	Medium	10	5	F/A	8	6	R	R	R	S
KT D17LC	Medium	10	6	F/A	9	7	R	S	R	HS
DT 538 LC	Medium	4	4	F/A	8	6	M	-	-	LS
DT 558LC	Medium	4	4	F/A	8	7	M	S	-	S
PD 7302LC[g]	Medium	10	0	F/A	6	7	R	R	-	-
PD 7305LC	Early	10	3	F	8	6	R	R	R	S
PD 7309LC	Medium	10	0	F/A	7	8	S	S	-	LS
PD 7312LC[f]	Medium	0	0	A/F	7	8	R	R	S	S
PD 7318LC	Medium	10	0	F/A	8	7	R	R	-	LS
PD 7319LC	Medium	10	1	F/A	8	7	-	R	-	S

[a] Black shank resistance levels are based on a limited number of field tests and subject to change.
[b] F or A refers to use as a fire-cured or air-cured variety. F/A indicates either use with predominant use given first.
[c] Relative yield scores based on performance under disease-free conditions. Relative yield and quality scores given on a 0-10 scale, with 10 being best for the predominant use.
[d] R = highly resistant; M = medium resistance; S = susceptible.
[e] Dash (-) means that resistance level is unknown or not rated at present.
[f] LS = less susceptible; S = susceptible; HS = highly susceptible
[g] KY 171, PD 7302LC, and PD 7312LC have medium resistance to Fusarium wilt.

Table 2. Yield and Quality Grade Index[a] for 2018-2019 dark fire-cured variety trials at Princeton and Murray, KY, and Springfield, TN.

Variety	Princeton KY		Murray KY		Springfield TN		Average		2018-2019 Black Shank % Survival[b]
	Yield (lbs/A)	Quality Grade Index	Yield (lbs/A)	Quality Grade Index	Yield (lbs/A)	Quality Grade Index	Yield (lbs/A)	Quality Grade Index	
NL Madole LC	3258	72.9	3040	64.1	2809	50	3035	62.3	0
TN D950	3468	66.5	2787	56.7	2661	47	2972	56.7	41
DT 538LC	3190	68.1	2633	58.4	2899	50	2907	58.8	26
DT 558LC	3335	65.7	2999	56.3	2921	52	3085	58.0	56
PD 7305LC	3467	67.0	2764	58.3	2828	39	3019	54.8	45
PD 7309LC	3116	72.0	2977	67.0	2714	55	2935	64.7	0
PD 7312LC	3326	60.4	2927	64.6	2979	47	3077	57.3	0
PD 7318LC	3277	69.8	3029	64.9	2890	53	3065	62.6	0
PD 7319LC	3188	64.1	3190	61.2	3040	53	3139	59.4	6
KT D6LC	3915	64.7	2921	60.8	3096	51	3310	58.8	63
KT D8LC	3777	65.1	3041	62.5	3134	47	3317	58.2	63
KT D14LC	3290	65.9	2770	61.6	2863	48	2974	58.5	66
KT D17LC	3607	67.4	2969	55.6	2993	47	3190	56.6	81
Mean	3401	67.0	2926	61.0	2910	49	3079	59.0	34

[a] Yield and quality grade index data averaged over 2018 and 2019. Quality grade index is a 0-100 numerical representation of federal grade received and is a weighted average of all stalk positions.
[b] Mean survival in two race 1 black shank nurseries located in Tennessee and one race 1 nursery located in Kentucky.

Table 3. Yield and Quality Grade Index[a] for 2018-2019 dark air-cured variety trials at Princeton and Murray, KY, and Springfield, TN.

Variety	Princeton KY		Murray KY		Springfield TN		Average		2018-2019
	Yield (lbs/A)	Quality Grade Index	Yield (lbs/A)	Quality Grade Index	Yield (lbs/A)	Quality Grade Index	Yield (lbs/A)	Quality Grade Index	Black Shank % Survival[b]
NL Madole LC	2781	45.4	2951	29.6	2795	73	2842	49.3	0
KY 171LC	3003	33.7	2735	28.1	2759	64	2832	41.9	0
DT 538LC	2993	36.9	2786	29.2	2756	55	2845	40.3	26
DT 558LC	3026	41.8	2735	30.5	2688	59	2816	43.8	56
PD 7309LC	2953	36.5	2768	37.2	2608	74	2776	49.2	0
PD 7312LC	2970	30.3	2755	29.4	2820	57	2848	38.9	0
PD 7318LC	2968	35.4	3080	33.3	2741	70	2930	46.2	0
PD 7319LC	2860	36.3	3084	22.6	3015	57	2986	38.6	6
KT D6LC	3040	35.0	3071	25.6	2992	58	3034	39.5	63
KT D8LC	3144	33.0	2869	19.0	2842	59	2952	37.0	63
KT D14LC	2844	30.5	2729	20.3	2727	50	2767	33.6	66
KT D17LC	2940	32.9	3120	24.1	2864	53	2975	36.7	81
Mean	2960	36.0	2890	27.0	2801	61	2884	41.0	34

[a] Yield and quality grade index data averaged over 2018 and 2019. Quality grade index is a 0-100 numerical representation of federal grade received and is a weighted average of all stalk positions.

[b] Mean survival in two race 1 black shank nurseries located in Tennessee and one race 1 nursery located in Kentucky.

KT D17LC is the latest dark tobacco variety release from the Kentucky-Tennessee Tobacco Improvement Initiative (KTTII). KT D17LC has high yield potential and superior black shank resistance in comparison to current dark fire-cured tobacco cultivars. It has level 10 resistance to race 0 and level 6 resistance to race 1 black shank. KT D17LC also has high resistance to wildfire and black root rot, but it has no resistance to tobacco mosaic virus, and it is highly susceptible to angular leaf spot. The cured leaf quality of KT D17LC is superior to previous varieties released by KTTII, but it performs better when fire-cured in comparison to air-cured. The agronomic characteristics of KT D17LC are much more similar to Narrow Leaf Madole than are previous KTTII varieties. The only pronounced difference is for leaf width; like most dark varieties, KT D17LC has wider leaves than does NL Madole. The leaf width of KT D17LC is similar to KT D14LC, but not as wide as leaves of KT D6LC. Leaf length of KT D17LC is similar to NL Madole, but shorter than KT D6LC and KT D14LC; conversely leaves of KT D17LC are longer than those of KY 171LC. Leaf number, internode length, and stalk size of KT D17LC are similar to other dark tobacco varieties. The growth habit of KT D17LC is intermediate between KT D6LC and NL Madole; in terms of erectness, KT D17LC more closely resembles NL Madole than do previous KT varieties. KT D17LC is later maturing in comparison to KY 171LC and NL Madole, but it is somewhat earlier than KT D14LC and KT D6LC.

KT D4LC was discontinued in 2013. For growers who would like to grow another variety with very similar agronomic characteristics and disease resistance to KT D4LC, KT D8LC is recommended.

KT D6LC is a hybrid of KT D4LC x TN D950. It is a fire-cured variety with early-to-medium maturity, semi-erect growth habit, and fairly smooth leaf texture. It has not been highly recommended as an air-cured variety but has performed relatively well under good air-curing conditions. KT D6LC has excellent yield potential (3,400 lb/A) and usually has higher cured leaf quality than KT D8LC or TN D950. It has medium resistance to race 0 and race 1 black shank (but slightly lower than KT D8LC, DT 538LC, or DT 558LC), and high resistance to black root rot, tobacco mosaic virus, and wildfire. When KT D6LC is transplanted in early May, physiological maturity characteristics at the end of the season can be much like TN D950, with rapid leaf maturity occurring about five weeks after topping.

KT D8LC has a very erect growth habit with medium maturity and leaves light in color similar to VA 359. Spacing between leaves is closer than most other varieties and it will typically have three to four more leaves than other varieties topped to the same height on the stalk. It has coarse leaf texture with cured leaf quality that is usually lower than most other varieties. KT D8LC will perform relatively well as a fire-cured or air-cured variety. KT D8LC has medium resistance to race 0 and race 1 black shank but no resistance to black root rot, tobacco mosaic virus, or wildfire. KT D8LC has excellent yield potential (3,600 lb/A).

KY 160 is a minor air-cured variety with medium maturity and relatively low yield potential (2,600 lb/A) but excellent cured leaf quality. It has a semi-erect growth habit with long, narrow leaves and very smooth leaf texture. KY 160 has high resistance to tobacco mosaic virus.

KY 171 is an air-cured or fire-cured variety with medium maturity and good yield (3,100 lb/A) and cured leaf quality. It has a semi-erect growth habit with coarse leaf texture and good curing characteristics. KY 171 has high resistance to black root rot and tobacco mosaic virus, medium resistance to Fusarium wilt, and performs better than many other varieties when transplanted early (prior to May 15). KY 171 can be a good choice for first cures transplanted in early May for double-crop, fire-curing, provided that black shank is not a concern.

Little Crittenden is typically an air-cured variety but also performs well as a fire-cured variety. It has medium-to-late maturity with fair yield (3,000 lb/A) but excellent cured leaf quality. Little Crittenden has a semi-erect growth habit with long leaves that have considerable crinkle and fairly coarse texture. It has very good curing characteristics and excellent holdability similar to Narrowleaf Madole. Little Crittenden

has no resistance to black shank, black root rot, tobacco mosaic virus, or wildfire, but it is less susceptible to angular leaf spot.

Narrowleaf Madole LC is still a popular dark tobacco variety, but the increased expansion of black shank in dark tobacco production areas and improved black shank resistance in new dark varieties have decreased the use of Narrowleaf Madole. It can be used as a fire-cured or air-cured variety and has medium-late maturity with good yield (3,200 lb/A). It is known for its excellent curing characteristics and cured leaf quality. Narrowleaf Madole LC has a very prostrate growth habit with long, drooping leaves and a smooth leaf texture. Narrowleaf Madole LC also has excellent holdability and can typically remain in the field longer after topping than any other variety before harvesting. However, it is somewhat more prone to leaf breakage at harvest due to its prostrate nature. It generally does not perform well when transplanted early (prior to May 15) when cool, damp conditions commonly occur, and therefore is usually not a good choice for first cures transplanted early for double-crop curing. Narrowleaf Madole LC has no disease resistance.

NS (Neil Smith) Madole is a fire-cured, more minor variety that is used for cigar-wrapper style markets. It has a prostrate growth habit similar to Narrowleaf Madole LC, but earlier maturity and a more open-textured smooth leaf surface, somewhat like TR Madole. NS Madole has excellent leaf quality but only fair yield potential (3,000 lb/A). NS Madole has no disease resistance.

PD 7302LC has medium maturity, with excellent resistance to race 0 black shank but no resistance to race 1 black shank. It also has high resistance to black root rot and tobacco mosaic virus, and medium resistance to Fusarium wilt. PD 7302LC can be used as a fire-cured or air-cured variety. It has a slightly upright growth habit, with good yield (3,200 lb/A) and curing characteristics. Growth habit and appearance of PD 7302LC are most similar to KY 171. PD 7302LC is a good choice for early transplanted first cures in double-crop, fire-cured tobacco where race 1 black shank is not a concern.

PD 7305LC is a fire-cured variety that is very similar to TN D950 in most characteristics including prostrate growth habit, early maturity, smooth leaf texture, and good yield potential (3,100 lb/A). Similar to TN D950, rapid leaf maturity can occur in PD 7305LC at about five weeks after topping. Like PD 7302LC, PD 7309LC, and PD 7318LC, PD 7305LC has excellent resistance to race 0 black shank. Resistance to race 1 black shank in PD 7305LC is similar to TN D950. PD 7305LC is also highly resistant to black root rot, tobacco mosaic virus, and wildfire. Like TN D950, PD 7305LC may require earlier firing and more firing to drive green out of the leaf. PD 7305LC should also have some potential for use in the cigar-wrapper style market due to its fairly smooth leaf texture and may also be a good choice for first cures transplanted in early May for double-crop curing.

PD 7309LC has medium maturity with excellent resistance to race 0 black shank. It is not resistant to race 1 black shank, black root rot, or tobacco mosaic virus, but it is less susceptible to angular leaf spot than most other varieties. It is a slightly more prostrate variety than PD 7302LC with good yield (3,200 lb/A) and curing characteristics. Other characteristics of PD 7309LC are most similar to Narrowleaf Madole LC. PD 7309LC can be used as a fire-cured or air-cured variety.

PD 7312LC is a hybrid of KY 171 x Narrowleaf Madole LC that has good yield and excellent quality characteristics for dark air-cured and fire-cured tobacco. PD 7312LC has no resistance to black shank but has high resistance to black root rot and tobacco mosaic virus and medium resistance to Fusarium wilt.

PD 7318LC is another hybrid that shows similarities to PD 7309LC in growth habit and TN D950 in leaf color. PD 7318LC has excellent resistance to race 0 black shank but no resistance to race 1 black shank. PD 7318LC is less susceptible to angular leaf spot. PD 7318LC has excellent yield (3,400 lb/A) and good curing/leaf quality characteristics. In addition, PD 7318LC also has high resistance to black root rot and tobacco mosaic virus. PD 7318LC is predominantly a fire-cured variety and may be a good choice for early transplanted first cures in double-crop, fire-cured tobacco where race 1 black shank is not a concern. Stalk size of PD 7318LC may be slightly larger than many other dark varieties, although not as large as DF 911.

PD 7319LC is another hybrid that has medium maturity and has performed well as an air-cured or fire-cured variety. PD 7319LC has excellent resistance to race 0 black shank, very low resistance to race 1 black shank, and resistance to tobacco mosaic virus. Race 1 black shank resistance in PD 7319LC is very low (similar to VA 359), and it is not a good choice for fields where race 1 black shank is known to exist. Yield characteristics of PD 7319LC are similar to PD 7309LC and PD 7318LC (3,300 lbs/A). Quality characteristics for PD 7319LC are also similar to PD 7309LC and PD 7318LC.

TN D950 is a fire-cured variety with early maturity and a very prostrate growth habit. It has excellent yield potential (3,200 lb/A) but may produce only fair cured leaf quality when not cured properly. Leaves of TN D950 have a smooth texture and are darker green, containing more chlorophyll (green leaf pigment) than most other dark tobacco varieties. TN D950 may require earlier and more firing to help drive green out of the cured leaf. TN D950 has medium resistance to race 0 and race 1 black shank (slightly lower than DT 538LC, DT 558LC, KT D6LC, and KT D8LC), and high resistance to black root rot, tobacco mosaic virus, and wildfire. However, TN D950 is highly susceptible to angular leaf spot. Rapid leaf maturity can occur in TN D950 at four to five weeks after topping. Due to its smooth leaf texture, TN D950 has potential for use in cigar-wrapper style markets. Due to its early maturity and black root rot resistance, TN D950 can be a good choice for first cures transplanted in early May for double-crop curing.

TR Madole is a minor variety that is typically fire-cured. It has early-to-medium maturity with good yield (3,100 lb/A) and fair cured leaf quality characteristics. It has a very prostrate growth habit and is an easy-curing variety similar to Narrowleaf Madole. TR Madole has very characteristic rounded top leaves with a fairly smooth, open-textured leaf surface, which makes it somewhat well suited to cigar-wrapper style markets. TR Madole has no disease resistance.

VA 309 can be used as an air-cured or fire-cured variety. It has early-to-medium maturity with fair yield (3,000 lb/A) and cured leaf quality characteristics. VA 309 has a semi-erect growth habit with a fairly smooth leaf texture, making it a good choice for cigar-wrapper style markets. It has low-medium resistance to race 0 and race 1 black shank.

VA 359 is typically used as an air-cured variety but may also be fire-cured. It has early-to-medium maturity and good yield potential (3,100 lb/A). It has an erect growth habit but may appear to be more variable in the field than many other varieties. VA 359 has leaves lighter in color than most other varieties. VA 359 has excellent handling and cured leaf quality characteristics and cures to a light brown color. VA 359 has low resistance to race 0 and race 1 black shank and is only a marginal choice for black shank fields, with acceptable survival expected only in very mild cases.

Management of Tobacco Float Systems

Bob Pearce, Andy Bailey, David Reed, Matthew Vann, Chuck Johnson, Emily Pfeufer, Lindsey Thiessen, and Hannah Burrack

The true value of a quality transplant lies in its potential to produce a high yielding plant at the end of the growing season. While good quality transplants can still result in low yields if fields are poorly managed, high yields are even more difficult to rescue from poor-quality transplants.

Many tobacco growers have the knowledge and skills necessary to grow good quality transplants, but some do not have the time to do the job well. For them, the best decision may be to purchase transplants and allow someone else to absorb the risks of transplant production. Growers who derive a significant portion of their farm income from transplant sales tend to spend more time managing their float facilities than growers who grow transplants only for their own use, but that does not mean that purchased plants are always better quality than those grown on farm. Transplant buyers should consider carefully the reputation of the transplant producer, ask questions about their management practices, request spray records for the purchased portion of the crop, and carefully inspect transplants upon delivery.

Transporting live plants over long distances increases the risk of spreading certain plant diseases more rapidly than would occur under natural conditions. Transplants may be infected with a disease even though they appear healthy at the time of delivery. If you choose to purchase transplants, working with a local producer is strongly recommended to minimize the risk of introducing diseases, such as blue mold or tomato spotted wilt virus, and to help stimulate the local farm economy.

For growers who choose to produce their own transplants, typical float systems currently used are direct seeding in unheated outdoor float beds or direct seeding into float beds in heated greenhouses. Table 1 shows a relative comparison of these systems. Some growers may use both systems, seeding in a heated greenhouse and moving plants to an unheated bed after germination in order to reseed the greenhouse.

The US Tobacco Good Agricultural Practice (GAP) Program requires complete records for all transplants used, regardless of whether they were grown on your farm or purchased. Information to be recorded includes seed lot number, date sowed, and all chemical applications made during transplant production. If you purchase plants be sure to request this information from the transplant producer to include in your GAP records.

Tray Selection

Tray Types

Most trays used in tobacco float systems are made of expanded polystyrene (EPS), and manufacturers control the density of the tray by the amount of material injected into the mold. Higher density trays tend to be more durable and have a longer useful life than low density trays, but they also tend to be more expensive. In some cases, an inexpensive low-density tray may be desired by those who sell finished plants and have difficulty getting trays returned or are concerned about potential disease with returned trays. Some problems have been reported with roots growing into the walls of low-density trays, making it difficult to remove the plants.

Trays made of a solid plastic material have been developed as an alternative to EPS trays. The plastic trays are designed to trap air beneath the tray so that it will float despite being much heavier than EPS trays. The expected advantages of the plastic tray are a longer useful life and potentially more effective clean-up and sanitation when compared to EPS trays. Potential disadvantages include the weight of the tray, plants falling out of the trays prematurely during transport and setting, and the initial investment cost of the trays. The trays that have been performance tested match in size and cell number to the 288 cell EPS trays and can be used with most current seeding equipment. Plastic trays have only been available for a few years so the expected useful life of the tray or the impact on disease

Table 1. Relative advantages and disadvantages of tobacco float systems.

	Float Bed Type	
Characteristic	**Outside**	**Greenhouse**
Labor requirement	Medium	Low
Cost per plant	Low	High
Target usable plants (%)	80	90
Management intensity	High	High
Risk of plant loss	High	Medium
Risk of introduced disease	Low	Low
Uniformity of plants	Low	Medium
Degree of grower control	Low	High
Time to usable plants (weeks)	8 to 10	7 to 9

Table 2. Production of usable burley tobacco transplants in selected soilless media and tray combinations

	Usable Plants (%)			
Brand of Media	**EPS tray**	**Plastic tray 1**	**Plastic tray 2**	**Media Avg.**
Carolina Choice	83.3	89.1	89.1	87.2
Promix TA	87.7	89.1	86.6	87.8
Southern States	84.8	90.5	91.7	89.0
Speedling Fortified	89.6	89.0	90.5	89.7
Sunshine Ag-Lite	87.3	88.5	91.6	89.1
Sunshine LT 5	83.8	86.0	89.7	86.5
The Gold	88.8	88.7	89.5	89.0
Workman's	83.1	88.0	89.4	86.8
Tray Avg.	86.1	88.6	89.8	

potential as the trays age have not yet been tested. Tests of new trays (both EPS and plastic) in the greenhouse show minimal difference in plant growth and usable transplant production (Table 2). No differences in field performance were observed for transplants grown in plastic float trays as compared to plants grown in EPS trays.

Tray Height and Cell Number

Trays may also differ in their height or depth measurements. A "shallow" tray has the same length and width as a regular tray but is only 1.5 inches deep as compared to the 2.5-inch depth of a regular tray. In limited side-by-side comparisons, shallow trays had fewer dry cells, slightly lower germination, and slightly more spiral roots than regular trays (Table 3). There was no difference in the production of usable transplants. The field performance of plants produced in shallow trays has not been significantly different from plants grown in deeper trays. The advantages of the shallow trays include reduced amount of soilless media needed, reduced space for tray storage, and reduced volume of waste at the end of the tray's useful life.

The choice of cell number per tray comes down to maximizing the number of plants produced per unit area while still producing healthy plants of sufficient size for easy handling. The outside dimensions of most float trays are approximately the same, so as the number of cells increases, the cell volume decreases. However, the depth of the tray and cell design can influence cell volume. In general, as the cell volume decreases, so does the optimum finished plant size. Smaller plants are not a problem for growers using carousel setters, but those with finger-type setters may have difficulty setting smaller plants deep enough. Tray dimensions vary slightly from one manufacturer to another. Be sure that the tray you select matches the dibble board and seeder you will use. Most tobacco transplants are currently being grown in 288-cell trays, with some being grown in 242-cell trays. Trays with higher cell numbers (338 and higher) have been used successfully by some greenhouse operators in the past, but more time and a greater level of management are needed for grown usable transplants at these higher densities.

Tray Disposal

When trays have deteriorated to the point that they can no longer be reasonably cleaned and sanitized, they should be disposed of in a responsible manner. Burning trays is not recommended, as this can result in the production of noxious smoke. Disposing of used trays in an approved landfill is the best option if EPS trays are allowed.

Table 3. Greenhouse performance of float trays.

Tray type	Dry Cells (%)	Germination (%)	Spiral Root (%)	Usable Plants (%)
Regular	0.8	97.4	1.9	91.4
Shallow	0.1	96.7	2.8	91.0
LSD 0.05*	0.3	0.5	0.6	NS

* Small differences between treatments that are less than this are not considered to be real differences due to the treatment but are thought to be due to random error and normal variability in plant growth.

Tray Sanitation and Care

A good sanitation program is critical for consistent success in the float system. For many of the diseases that are problems in float plants, sanitation is the first line of defense. Sanitizing trays is difficult because of the porous nature of polystyrene. As the trays age, they become even more porous. With each successive use, more roots grow into the tray, which allows pathogenic organisms to become embedded so deeply that they are difficult to reach with sanitizing agents.

Cleaning and Storage

Field soil is often infested with soil-inhabiting pathogens that cause diseases in the float system. After trays have been used to grow a crop of transplants and been taken to the field for transplanting, they may become contaminated if the trays came in contact with soil. Trays should be rinsed off immediately after transplanting to remove any media, plant debris, or field soil.

The surest way to reduce the risk of diseases carried over in trays is to purchase new trays each season. Previously used trays, which may be contaminated with pathogens, should be rinsed prior to fall storage and disinfected just before seeding in the spring. They should be stored indoors out of direct sunlight. Do not store trays for long periods of time in a greenhouse, where ultraviolet light and heat will cause deterioration and damage. Avoid storing sanitized trays in areas where trays may come into contact with soil or debris, or cover trays with plastic or a tarp. Take appropriate steps to protect trays from damage due to the nesting of small rodents and birds.

Tray Sanitization

EPS trays become more porous as they age, often leading to increased problems with disease carryover in older trays. Effective tray sanitation means the disinfecting agent must reach the resting states of pathogens in all the tiny cavities throughout the tray. Steam, chlorine bleach, and quaternary ammonium chloride salts are available disinfectants. None of these disinfectants can completely eliminate pathogens in contaminated trays, and each has positive and negative points, as discussed below.

Steam has been shown by university studies to be an effective way to reduce potential plant pathogens in used EPS trays. Steam sterilization of trays is especially recommended for commercial transplant producers. Steaming trays to a temperature of 160 to 175°F for at least 30 minutes has been demonstrated to successfully reduce disease problems in used trays. The key with all steam or high temperature treatments is to achieve and hold the desired temperature through the middle of the stack of trays for the duration of the treatment. EPS trays exposed to temperatures above 180°F may begin to soften and become deformed.

In actual practice, results with chlorine bleach have been varied, often due to poor technique. Research has shown little benefit of using more than 1 part bleach to 9 parts water (10% solution). Any commercially available household bleach can be used to make the sterilizing solution. Industrial-type bleaches cost more and don't add any additional benefit. Bleaches work best when the trays are first washed with soapy water, then dipped several times over a few seconds into clean 10% bleach solution, and covered with a tarp or plastic to keep them wet with the bleaching solution overnight. Because organic matter

reduces the effectiveness of bleach over time, a fresh solution should be made up every two hours or whenever it becomes dirty, whichever comes first. After the overnight exposure period, the bleach solution should be washed from the trays with clean water or water plus a quaternary ammonium chloride salts product, followed by aeration to eliminate any residual chlorine. Without proper aeration and post-washes, salt residues can cause serious plant growth problems, especially with older trays that tend to soak up more materials. Worker safety issues are also an important consideration when working with bleach. Workers should be provided with appropriate personal protective equipment to minimize eye and skin contact with bleach. Bleaching of trays should be done in a well-ventilated area.

Quaternary ammonium chloride salts and other types of cleaners such as Greenshield, Physan-20, and CC-15 have been shown to be effective for cleaning and disinfecting hard surfaces in and around greenhouses. They are less effective in reducing pathogen levels in porous EPS float trays. In university tests, they have always provided some control as compared to using soap washes only, but they have typically been inferior to steam or bleach for sanitizing trays. These products do not damage trays like steam, are less corrosive to greenhouse surfaces than bleach, and are less irritating than bleach for workers. They are also less toxic to plants than bleach, so the greatest benefit for these products may be in the final tray rinse following bleach sanitation. These products can also be used on exposed surfaces in the greenhouse. Follow the product label for directions for proper dilution rates.

Water Quality

Untreated surface water may contain disease-causing organisms and should never be used for growing float plants. Treated water from most municipal and county water systems has been found to be suitable for use in the float system, although in a few water districts, the alkalinity levels have been found to be above acceptable levels.

Water from private wells occasionally has higher-than-desired levels of alkalinity. A preliminary check of water quality can be made with a conductivity meter and swimming pool test strips that measure pH and alkalinity. Conductivity readings above 1.2 milli-siemens/centimeter (mS/cm) or alkalinity above 180 parts per million suggest the need for a complete water analysis. Water source analyses for plant growth are available from most labs that provide soil tests. In rare situations water quality problems may be severe enough to warrant switching to a different water source. For more information on water quality for float beds, see University of Kentucky Cooperative Extension publication AGR-164, *Water Quality Guidelines for Tobacco Float Systems* or NC State Extension publication AG-488-03, Producing Conventional Tobacco Transplants in Greenhouses – Water Quality.

Media Selection, Tray Filling and Seeding

Media Types

The three basic components of soilless media used in the float system are peat moss, perlite, and vermiculite. Peat is the brown material that is used in all soilless media to improve water and nutrient-holding capacity. Vermiculite is the shiny, flaky material, and perlite is the white material used in some media. Different brands of media have varying amounts of these components. Some have only peat and vermiculite; others have only peat and perlite; and still others have all three ingredients. Research to date has not indicated any particular combination of ingredients or brand of media to be consistently superior to others (Table 2). Year-to-year variability within the same brand of media can be quite high, so there is a need to continually check and adjust tray filling and seeding procedures each year.

Filling Trays

Careful attention to tray-filling procedures will minimize the occurrence of dry cells and spiral roots. In most cases, dry cells occur when the media bridges and does not reach the bottom of the tray or when a portion of the media sifts out the bottom of the tray. When this happens, water does not wick up to the top of the cell, and the seed in that cell will not germinate. A few dry cells (1% or less) should be considered normal. It is a good idea to check a few trays during tray filling to make sure that media is in the small hole at the bottom of the tray. If bridging of media is a consistent problem, try pouring it through a coarse mesh screen to remove sticks and clumps. If media is falling out the bottom of trays, you may need to add 1 or 2 quarts of water to each bag of media prior to tray filling. Wait 24 hours, if possible, to allow time for moisture to evenly adjust.

Each year, there are a few cases in which large groups of trays fail to wick-up water after a reasonable period of time. Many of these situations have been traced back to the use of media left over from the previous year. During storage, the media dries out, and the wetting agents tend to break down over time, causing the media to be difficult to rewet. The use of leftover media should be avoided if possible; however, if it is known that the media is old, try adding 2 or 3 quarts of water per bag at least a day before seeding. It is also a good idea to keep an intact empty bag or to record the lot numbers from the bags of media used, as this information can be very helpful in tracking down the source of problems. Before seeding the entire bed or greenhouse, it may also be a good idea to fill and float a few trays the day before seeding to evaluate how well media will wick.

Often wicking can be seen within 5 to 10 minutes of floating trays. It should never take longer than 1 to 2 hours after floating for wicking to occur. For mild wicking problems where dry cells are slightly above normal, misting trays over the top for 10 minutes or so per 1000 ft2 of float bed (400 trays) using the fine mist setting on a nozzle attached to a garden hose can sometimes help improve wicking. Be sure to use the fine mist setting and not large droplets so seed are not dislodged from cells. Placing objects such as boards on trays in order to push the tray down further into the water can also help improve mild wicking problems. If dry cells are much over about 10%, these methods will provide little or no improvement. If fresh media is used, trays should wick well and none of these methods should be needed.

Seeding

After the trays are filled, a small indentation, or "dibble," should be made in the surface of the media. Research has shown that seed germination is much more consistent in dibbled trays than in non-dibbled trays. The dibble board or rolling dibbler should be matched to the brand of tray so that the dibble mark

is as close as possible to the center of each cell. The dibble should be a half- to three-fourths-inch deep with relatively smooth sides to allow the seed to roll to the bottom of the dibble. Handle the trays with care after dibbling to avoid collapsing the dibble prior to seeding.

Like the dibbler, the seeder should be matched to the brand of tray you have. There are slight differences in the dimensions of trays from different manufacturers. If the seeder is not matched to the tray, seeds might be placed near the edge of the cell and will be less likely to germinate. After seeding, examine the trays to ensure that there is only one seed in each cell. The seed should be near the center of the cell and at the bottom of the dibble. Seeds that fall outside the dibble or on the side of the dibble mark are more likely to experience problems with germination or spiral root.

Spiral Root and Germination Issues

Spiral root is a term used to describe a germinating float plant in which the emerging root does not grow down into the media but instead grows on the surface, often looping around the plant (Figure 1). Spiral root is thought to be the result of physical damage to the root tip as the root attempts to break out of the seed and pellet. Whether or not a particular plant will have spiral root is determined by a complex interaction between the variety, the seed/pellet, media properties, and weather conditions. The burley variety KY 14 x L8 and the dark variety Narrowleaf Madole typically have a higher incidence of spiral root than other varieties, regardless of other factors.

The incidence of spiral root has decreased in recent years, due in part to changes made to the pellets by some tobacco seed companies. Nevertheless, spiral root can still be an occasional problem that results in a significant reduction in usable plants. To minimize spiral roots, avoid packing media tightly into the trays. Trays should be allowed to fill by gravity without additional pressure applied to the top of the tray.

If spiral root seedlings are consistently a problem, a light covering of media over the seed may be considered. A light dusting is all that is needed; the tops of the seed should remain visible. Research in Virginia has suggested that in many cases all that is needed is slight jarring of the tray after seeding to settle the seed and gently collapse the dibble around the seed. Often growers who seed at one location and then move trays by wagon or truck to the greenhouse report fewer problems with spiral root, most likely due to the shaking of the tray while transporting.

Figure 1. Spiral root of a burley tobacco transplant.

Fertilizer Selection and Use

Choose a fertilizer that is suitable for use in the float system. Many water-soluble fertilizers sold at garden shops do not contain the proper balance of nutrients in the right form for tobacco transplants. Specifically, avoid fertilizers which have a high proportion of nitrogen in the form of urea. Look for a fertilizer with mostly nitrate nitrogen and little or no urea. In the float system, urea can be converted to nitrite, which is toxic to plants. Information about the nitrogen source should be on the product label. If it is not there, don't buy that product for the float system. The use of 20-20-20 should be avoided due to the low nitrate content, high urea content, and comparative high phosphate content.

Research has shown that tobacco transplants do not need a high level of phosphate. Some research even suggests that there is a better balance of top and root growth if phosphate levels are kept lower. Look for a fertilizer with low phosphate, such as 20-10-20, 16-5-16, 15-5-15, 13-2-13, 16-4-16, etc. Some growers add Epsom salts ($MgSO4$) to the float water; however, research has shown it to have little impact on the health and growth of transplants. Foliar application of any fertilizer to float plants is not recommended, as moderate to severe leaf burn can result.

Adding Fertilizer

Fertilizer can be added to float water just at seeding or within seven to 10 days after seeding. The advantage of fertilizing at seeding is convenience, in that the fertilizer can be dissolved in a bucket, poured into the bed, and mixed easily. The disadvantage is that salts can build up at the media surface during hot, sunny conditions. As water evaporates from the media surface, the fertilizer salts can be wicked up and deposited where they may cause damage to the germinating seed. Fertilizer added at seeding can also contribute to algae growth in the water and on tray surfaces.

Delaying the addition of fertilizer until a few days after seeding minimizes the risk of salt damage to young seedlings. When adding fertilizer or chemicals to an established float bed, the water should be circulated for 2 to 4 hours depending on the size of the bed to ensure even distribution. Many producers have built simple distribution systems with PVC pipe or hoses to help mix fertilizers and chemicals throughout large float beds without having to remove trays. The distribution systems are typically connected to small, submersible pumps that can be lowered into a bucket of dissolved fertilizer, then moved into the bed to provide circulation for mixing. Pumps and hoses should be sanitized with an approved greenhouse disinfectant to avoid spreading diseases between beds. The addition of fertilizer should not be delayed by more than 7 to 10 days after seeding, or a lag in plant growth may result.

Determining the Amount of Fertilizer Needed

Over-fertilization of float plants is a common mistake. The recommended level of fertilization is no more than 100 ppm nitrogen. This is equivalent to 4.2 pounds of 20-10-20 or 5.6 lb of 15-5-15/1,000 gallons of water. To determine the gallons of water in a float bed, use the following formula:

(number of trays the bed holds) x (depth of water in inches) x 1.64 = gallons of water.

When transplants are not developing fast enough, some growers are tempted to add more fertilizer to push the plants along. At high rates of fertilizer, plant growth will be very lush, making the plants susceptible to bacterial soft rots, *Pythium* root rot, and collar rot. Under-fertilized plants grow more slowly and are more susceptible to diseases such as target spot.

Monitor Fertility Levels

The incidence of improper fertilization can be reduced by investing in a conductivity meter and monitoring the salt concentration on a regular basis. A conductivity meter measures how easily a current passes through a solution. The higher the salt content of the solution, the greater the current. Conductivity meters need to be calibrated periodically to ensure proper operation. Check the instructions that came with the meter or visit your county Extension office for help calibrating. Some of the newest meters require a specific solution that must be purchased from the manufacturer be used for calibration, so carefully read the instructions. To use the meter, measure the reading of your water source before fertilizing. Most water sources have a conductivity of between 0.1 and 0.5 mS/cm before fertilization. However, water with conductivity levels above 1.2 mS/cm may become too salty for optimum plant growth after fertilizer is added. Calculate the amount of fertilizer needed for the bed. Add the fertilizer to the bed and mix thoroughly before reading again. Readings can fluctuate for as much as 12 hours after adding fertilizer. The reading should go up by 0.5 to 0.9 mS/cm compared to the unfertilized water, depending on the type of fertilizer used. For the most commonly used 20-10-20 formulations, the reading increases by 0.3 mS/cm for every 50 ppm N added. The reading obtained after fertilization should be the target level. If the reading falls below the target, add more fertilizer. If it is above the target, add water to dilute the fertilizer and avoid problems with over-fertilization. Many water-soluble fertilizers now have charts on the label to help with interpretation of conductivity readings. Some conductivity charts are listed in units of mmhos/cm which are the same as mS/cm.

Climate Control and Temperature Management

Tobacco seeds germinate best around 70 to 75°F. However, a slight fluctuation between nighttime and daytime temperatures may be beneficial for optimum plant growth. While cooler temperatures tend to slow germination and growth, higher temperatures are potentially more damaging to newly emerged seedlings. Temperatures that exceed 90°F may cause uneven germination and predispose plants to temperature stress. Young seedlings at the two- or three-leaf stage will often have scorched appearance on the leaf tips with a pale/translucent appearance to the body of the leaf after two or more hours of exposure to temperatures in excess of 100°F. A good rule is that if it's too hot to work in a greenhouse, it's too hot for the plants. Temperatures in excess of 100°F may be unavoidable on hot, sunny days, but every attempt should be made to manage the ventilation to reduce the length of time that plants are exposed to excessive heat.

Temperature Stresses

Chill injury can result when plants that have been exposed to high temperatures are then exposed to cooler air. Chill injury can also result from significant but normal swings of 25 to 30 degrees between daytime and nighttime temperatures. Burley tobacco is much more susceptible to chill injury than dark tobacco. Symptoms of chill injury are usually visible within two or three days and include an upward cupping of the leaf tips, constricted regions of the leaves, and a distinct yellowing of the bud. Chill injury may be most apparent in trays located on the outside walls of greenhouses. If severe bud damage occurs, sucker bud initiation may occur as the bud can no longer suppress the development of suckers. While the bud usually recovers from this damage and re-establishes control over the suckers, the sucker buds have already been initiated. They may begin to grow again if the plant is subjected to further stress. That stress often occurs after transplanting, when the sucker buds begin to develop into ground suckers that may result in plants with multiple stalks that are difficult to harvest and produce poor quality tobacco. Maintaining an even temperature that doesn't fluctuate too drastically can help reduce chill injury and potential ground sucker problems. Additional information regarding chill injury can be found in the NC State Extension publication AG-439-54, Cold Injury and Boron Deficiency in Tobacco Seedlings.

Monitoring and Regulating Temperatures

Accurate measurement is important for good control of temperature. Thermostats and thermometers exposed to direct sunlight will give false readings. Both devices should be shielded for accurate readings. Thermostats should not be located too close to doors and end walls or positioned too high above plant level. The most accurate results are obtained from shielded thermostats with forced air movement across the sensors.

Fans for ventilation are rated in CFMs, or cubic feet per minute. Typically, a greenhouse used for tobacco float plant production should have enough fan capacity to exchange three-fourths to 1 times the volume of air in a greenhouse per minute. Two fans allow for the ventilation to be staged so that the first fan comes on at a lower temperature than the second. Fans with more than one speed are more expensive but allow the speed to increase as the air temperature inside the greenhouse increases.

Shutters are designed to complement fans and should be located at the opposite end of the greenhouse. They should have an opening 1.25 to 1.5 times the size of the fan. Motorized shutters are best and should be on a thermostat set at 2 to 3 degrees cooler than the fans, so that they open before the fans come on. Alternatively, fans may be set on an 8- to 10-second delay, which will accomplish the same thing. To reduce chill injury damage, locate fans and shutters at least 3 ft above the plants to minimize drafts and improve the mixing of cooler air with the warmer air inside the greenhouse. Baffles can be used inside to deflect cool, incoming air up and away from the plants.

Side curtains (walls) allow natural air movement for good ventilation. Although they are cheaper to install and operate than fans, they do present some risk. A cool, rainy morning may rapidly change to a warm, sunny day. If no one is available to make sure the curtains are lowered, plant damage can occur

within minutes after the sun comes out. It is important to have someone at or near the greenhouse to lower curtains when needed. Automated curtains are an option but may offer less precise operation than fans. For the most control of the growing environment, both fans and curtains are recommended. A side curtain should, at its maximum, provide 1 ft of vertical opening per 10 ft of greenhouse width. A typical 36-ft-wide greenhouse may have a 3-ft side curtain that will drop 2 ft but may have 1 ft of plastic hanging down over the side, providing only 1 ft of effective ventilation. The best system would have a 5-ft side wall that could be opened to 3.5 to 4 ft to meet the required guideline for ventilation.

For more information, please see Kentucky Cooperative Extension publication ID-131, *Basics for Heating and Cooling Greenhouses for Tobacco Transplant Production*.

Humidity Management

Humidity can cause numerous problems inside a greenhouse or float system. As the warm, moist air comes in contact with cool surfaces, such as greenhouse plastic, support pipes, and float bed covers, it condenses as droplets. Water droplets can dislodge and fall to the trays, disturbing seeds and seedlings and knocking soil out of cells, which results in stand loss. High humidity also favors the development of disease problems, and can reduce the longevity of some metal components, such as heaters and supports, by promoting the development of rust. In greenhouses, the best control of condensation and moisture is through the proper control of ventilation and heating.

Sources of humidity in float systems. Excessive humidity is more common in greenhouses than in outdoor float beds, which tend to be well ventilated. Sources of humidity include evaporation from the float beds, transpiration as water moves through a plant's system and into the air, and the release of moisture during the combustion of natural gas or propane. Non-vented heaters will generate more humidity than vented heaters because all the heat, fumes, and water vapor are released into the greenhouse. Ventilation is essential for greenhouses with non-vented heating systems but is also a good idea for vented systems.

Regulating humidity. While ventilation seems counter-productive to keeping a greenhouse heated, ventilation replaces some of the warm, moist air with cooler, less humid air. Warm air can hold a lot more moisture than cooler air, a concept that can aid in regulating humidity.

Regulation of humidity can begin as the sun goes down in the evening. Turning a fan on or cracking a side curtain open pushes warm, humid air out of the greenhouse, replacing it with cooler, less humid air. The exchange of air can reduce condensation problems that tend to escalate as the inside air cools. This process will take only a few minutes of fan time to complete, but many producers are reluctant to use this method due to the cost of reheating the cooler air. The benefits often outweigh the cost during cooler weather periods by reducing the damage caused by condensation collecting and falling from the inner surface of the greenhouse onto trays. Many tobacco greenhouses have enough on-going air leakage around doors, curtains etc. that this one air exchange is sufficient to control moisture problems.

In greenhouses that are sealed very tight, additional air exchanges during the night or at daybreak may be necessary to control moisture problems. Using fans for nighttime or early-morning ventilation is generally safer than lowering side curtains due to possible injury from the sudden influx of cool air, though cracking a side curtain on the leeward side of the greenhouse is also an option for air exchange. Once the humid air has been exchanged, the fans (or curtains) should be switched back to automatic for temperature control.

Protecting plants from condensation. Other methods may be used to protect plants from the direct damage caused by dripping, but they do little to control the cause of condensation or reduce disease potential. Building the greenhouse or bed with a steeper pitch for the roof will reduce problems, because the condensation that forms will have a greater tendency to roll off the sides rather than drip. Some growers use bed covers at the plant level to protect plants from dripping. With this method three common problems occur: (1) the plants get too hot, (2) plants don't get enough light and have a tendency to elongate or stretch, and (3) plants may become attached to the cover and may be pulled from the trays as the covers are removed. The plant-level covers should be removed as soon as the plants are big enough (about dime size) to protect the cell from damage. There are also some commercial materials available that can be sprayed on interior surfaces of greenhouses to reduce surface tension in order to help water roll off the sides rather than drip.

Circulation Fans

Circulation fans are primarily designed to circulate air and prevent formation of hot and cold zones that could cause condensation and influence plant growth. Circulation fans should be located approximately 40 to 50 ft. apart, one-fourth of the house width from each side wall, and about halfway between plant level and the highest point of the roof. Ideally circulation fans on each side of a greenhouse should point in opposite directions to create a good circulation pattern and should be set to turn off when the ventilation fans are on. Circulation fans should not be pointed down at a sharp angle or they can increase evaporation on the tray surface and potentially increase salt accumulation at the soil surface, affecting germination and plant growth. An elliptical pattern of abnormal growth or injury across several trays and in front of a fan is generally an indication that a circulation fan is positioned at too steep an angle.

Circulation fans are also important in maintaining optimum temperatures at plant level. Since warm air rises, circulation fans help to direct warm air down toward the plants. A greenhouse without circulation fans or with circulation fans turned off may have temperatures 15 to 18 degrees lower at the plant level than just 4 ft. above the plant level.

Clipping

Proper clipping of float plants helps to toughen the plants, promotes uniformity, increases stem diameter, and aids in disease control. When done properly, clipping does not slow the growth of plants significantly, nor does it contribute to early blooming or ground sucker formation.

Procedures for Proper Clipping

When clipping is done properly, it actually aids in disease control by opening up the plant canopy to allow for greater light penetration and improved air circulation around the plants. Clipping equipment must be sanitized to avoid spreading diseases. The mower and surrounding frame should be thoroughly cleaned after each use and sprayed with a disinfecting solution of 10% bleach or a commercial greenhouse disinfectant. If left on metal surfaces, bleach will promote rust, so rinse all surfaces after 10 minutes of contact time. Disinfection between individual beds and greenhouses will reduce the potential for spreading disease.

The key to effective clipping of float plants is to make a clean cut and remove the clipped material from the area. To accomplish this, use a sharp blade and adjust the mower speed so that the clipped material is lifted off the plants and deposited in the bagger. A high blade speed will result in the material being ground to a pulp and being deposited back on the trays, thereby increasing the likelihood of certain diseases. A dull blade may tear the leaf, which may not heal properly as a result. A relatively low blade speed with a sharp blade works best. Although some vacuum is necessary to push clipped leaves into a leaf catcher, a high vacuum may pull plants from the trays or suck the trays up into the blade. Dispose of clippings at least 100 yards downwind from the transplant production facility to minimize the spread of diseases such as *Sclerotinia* collar rot. Gasoline-powered reel-type mowers have been used successfully for clipping plants. This type of mower tends to make a clean cut, producing large pieces of intact leaf and depositing them in a catcher with little or no grinding. Rotary mowers, however, may be easier to adjust and maintain. An improperly maintained or adjusted mower may result in improper clipping that could injure plants, reduce vigor, and promote disease development.

Timing and Frequency of Clipping

The first clipping is usually the most beneficial, and direct-seeded float plants should be clipped for the first time when the plant buds are approximately 1.5 to 2 inches above the tray surface. The cut should be made approximately 1 to 1.5 inches above the bud and ideally should remove no more than a 0.5 to 1 inch of leaf material. The first clipping promotes uniformity, particularly in outside direct-seeded beds where germination is often uneven. Smaller plants may not be clipped the first time but will benefit from more sunlight and less competition from plants that were taller before clipping. After the first clipping, plants should be clipped every five to seven days, depending on growth rate. Clipping frequency should be timed to remove no more than a half inch to 1 inch of leaf material at a time. Clipping too much leaf material in one pass increases the amount of debris deposited on leaves and may enhance disease development. Two passes may be necessary in cases of rank growth between clippings. Four to six clippings may be necessary to achieve the best plant quality. Seldom are more than six clippings necessary unless field planting is delayed due to weather. However, plants produced in trays with smaller cells (338) may require more frequent clipping. Plants that need to be held for some length of time before transplanting can be clipped additional times to help manage plant size and slow plant growth. Hard clipping (removing more than 1 inch of leaf material) should be avoided unless plant growth needs to be controlled. Plants should never be clipped so severely that buds are damaged. Plugged plants should be clipped for the first time approximately one to two weeks after plugging (as soon as the roots have established). The same guidelines that apply to clipping direct-seeded plants apply to plugs. Plugged plants should only require two or three clippings unless setting is delayed.

Pest Control in Tobacco Float Beds

The first line of defense in controlling pests is their exclusion from float beds. A good sanitation program will not eliminate pests from the system, but it will reduce their numbers and the likelihood that they will cause economic loss. In addition to disinfecting trays, a good sanitation program includes removing weeds from around the bed area prior to seeding and cleaning equipment used in and around the beds. Locate the float site away from tobacco fields, barns, and stripping rooms to reduce the chance of introducing pathogens into float beds.

Pesticides are useful tools for managing certain pest problems on tobacco seedlings. Many of the pesticides that are labeled for tobacco in the field, however, cannot be used in float beds. Check labels carefully to make sure that the products you intend to use are cleared for tobacco and are approved for use in greenhouses and outdoor float beds.

Several products containing the active ingredient acephate are labeled for use in float systems. Orthene 97 is labeled to use in tobacco greenhouses at a rate of ¾ Tablespoon in 3 gallons of water to cover 1000 square feet of bed surface area. Float water from treated beds should be disposed of on tobacco fields either as spray water or transplant barrel water. Generic products containing acephate may also be labeled for this use but with different use rates, consult and follow the label directions for all products used. The use of some Bt products such as Dipel may also be allowed for caterpillar control in greenhouses at rates of ½ to 2 teaspoons per gallon.

Management of Insect Pests

A variety of insects and other organisms that live in water or moist organic matter can cause problems or damage seedlings in the float system. Algae on the media surface and organisms that can grow in float water provide food for fungus gnats, shore flies, bloodworms, mosquito larvae, and waterfleas. Pillbugs, and even some scavenger beetles, can burrow into media, while slugs, cutworms, thrips, and aphids can feed on developing plants. Insect pests can uproot or eat and destroy many seedlings in a short period of time. In most cases, it is easier to prevent infestations that to control them once they have started. Regular inspection is necessary to catch developing problems before serious damage occurs.

Cultural Controls are Essential

Cultural controls are the primary defense against insect pest infestations. Good practices include:

- Keep doors, screens, and ventilators in good repair.
- Use clean or sterile media.
- Maintain a clean, closely mowed area around the greenhouse or float beds to eliminate shelter for insect pests.

- Eliminate pools of standing water on floors, and open water in float beds. Algal and moss growth in these areas can be sources of fungus gnat, shore fly, and mosquito problems.
- Remove all plants and any plant debris; thoroughly clean the greenhouse after each production cycle.
- If possible, keep the greenhouse open during the winter to eliminate tender insects like aphids, gnats, and whiteflies.
- Avoid overwatering and promote good ventilation to minimize wet areas conducive to fly breeding.

Bloodworms, Flies, Gnats, Mosquitoes, and Waterfleas

Bloodworms. Bloodworms are the small, red wriggling worms that live in float water green with algal growth. The red color comes from oxygen-carrying hemoglobin that allows it to develop in still, stagnant water. These gnat larvae have chewing mouthparts and generally feed on algae or other organic matter in the water. They may be found in plant roots that grow through the bottom of float trays, but they do not feed on them. These insects are similar to mosquitoes, but the adults (gnats) do not feed on blood or plants.

Shore flies. Shore flies also are small gnats with short antennae; heavy, darker bodies; and a pair of smoky wings with several distinct clear spots. They rest on plant foliage or most any surface around the float beds. The shore fly's life cycle is similar to that of the fungus gnat. The maggot-like yellow to brown larva is up to one-fourth inch long and does not have a distinct head. Both the larva and adult feed mostly on algae, but occasionally a larva will bore directly into the base of a small plant. These plants will break easily at the soil surface. The adults do not feed on plants but may spread soil pathogens that stick to their body as they crawl over media and move from tray to tray.

Fungus gnats. Occasionally, fungus gnat larvae can be serious pests. The legless white larvae with distinct black heads are scavengers that live and feed in decaying organic matter. Occasionally, they will chew on root hairs, enter the roots, or even attack the stem or crown of the plant. Damaged or infested plants grow poorly and may die.

The adults are small (one-eighth inch) black flies with long legs and antennae, tiny heads, and one pair of clear wings. Females lay tiny ribbons of yellowish-white eggs in the growing media that hatch in about four days. The larvae feed for about 14 days and then pupate in drier surface media. Adults live about a week. Under greenhouse conditions, they can complete a generation in three to four weeks.

Mosquitoes. Standing water in empty float beds can be a breeding site for large numbers of mosquitoes. In addition to being a painful nuisance, some of these mosquitoes can carry West Nile virus or types of encephalitis. If float water stands for more than a week after trays have been removed, mosquito dunks or granules containing Bt-i (*Bacillus thuringiensis israelensis*) should be added according to label directions. Mosquito dunks are not labeled for use while plants are on the water.

Waterfleas. Waterfleas are very small crustaceans that swim through the water with jerky movements. They are common in many temporary water puddles during the summer and can accidentally end up in float water. They feed on a wide range of small organisms that live in the water, especially algae. They are harmless, but massive numbers may cause concern.

Reducing Fly/Gnat Problems. Eliminate wet areas and standing puddles and provide good drainage in and around greenhouses or float beds. Have a minimum amount of exposed water surface. Using empty trays to fill the bed so open water is not available will reduce egg laying by mosquitoes and gnats.

Regularly clip grass along bed margins so these areas can dry quickly. Avoid letting clippings get into float water. They can provide food for gnats, etc.

Excessively wet media in trays attracts fungus gnats. Algal growth on the surface will attract shore flies. Keep moisture content optimum for plant growth but not above that level.

Yellow sticky cards (available from greenhouse supply stores) can be tacked to pot stakes or suspended in the area to monitor for buildup of fungus gnats or shore flies. An early insecticide treatment will be more effective than one applied when fly numbers are very high.

Foliar sprays of acephate (Orthene, etc.) can be used to reduce numbers of both species. However, they do not reach larvae in the media, so new adults will continue to be produced.

Slugs

Slugs can cause serious damage to float plants. They are active very early in the spring and can destroy small plants as they begin to grow. Slugs can enter from overgrown areas around the bed or may come from under plastic bed liners, stacked boards, etc. They feed at night or during overcast days and hide in cool, moist places when the sun is out. Their rasping mouthpart scrapes away at leaves and tender stems, producing holes or scars on the leaf surface. Slugs often leave behind silvery slime trails.

Reducing slug problems. Sanitation is very important for slug control. Keep the area around float beds free of plant debris (leaves, pulled weeds, etc.), old boards, bricks, or stones that provide cool, moist hiding places for slugs. Frequent clipping of plants along the outside margin of the beds will let the area dry out so it is less attractive to slugs. Slug baits containing iron phosphate or metaldehyde can be distributed along these areas, too. It is best to manage slugs before they get to the trays. Insecticides are not effective against slugs.

Cutworms

The variegated cutworm can cause serious problems in some greenhouse or float systems. The adult (a moth) flies in mid-March and lays clusters of about 60 eggs on the stems or leaves of low-growing plants. The smooth, pale gray to light brown larva has a row of pale spots down the center of its back. This cutworm feeds for three to four weeks and is about 1.6 inches long when full grown. Since their eggs are laid in clusters, entire trays of plants can be destroyed in a short time. The cutworms hide during the day in tray media and feed at night. When monitoring for these insects, look for cut plants or leaves with large sections removed.

Infestations often begin in trays along outer walls and spread in a circular pattern from that point. Feeding by small cutworms appears as notches along leaf margins and is easy to overlook. Feeding rate increases dramatically as the larvae grow, so extensive damage can seem to appear overnight. In fact, the cutworms are there usually for about two weeks before they eat enough to be noticed.

Reducing cutworm problems. Keep outside bed margins trimmed so plant growth is not attractive to moths. Keep doors closed or screened at night when moths are flying. Excess outside lighting will attract moths to an area. Checking trays along bed margins regularly for feeding damage to leaves is a good way to detect problems early. Foliar sprays of acephate (Orthene, etc.) or sprays of Bt insecticides (Dipel, etc.) will kill cutworms, and spot treatments on affected trays often provide control without the need to treat the entire greenhouse.

Pillbugs

Pillbugs are scavengers that live in decaying organic matter. They occasionally feed lightly on young plants, but the damage is minor. They do churn up and burrow into plant media, uprooting and killing small seedlings. Once they're in trays, it is difficult to control them. Their armored bodies protect them from insecticide spray droplets.

Pillbugs can only survive in humid air, so they hide under objects during the day. They are common under plastic, boards, stones, and other items resting on damp ground. They will also congregate in grassy or overgrown areas.

Reducing pillbug problems. Cleanup and regular mowing along the outside of bed structures will remove hiding places and allow areas to dry. Old plastic liners provide cover for pillbugs and should be removed. Pillbugs will leave for better conditions. Ventilation to reduce excess humidity also helps to lower problems with pillbugs and slugs.

Leave a few small pieces of plywood on the ground and check under them regularly for accumulations of pillbugs or slugs. If many are found, the area can be sprayed with an insecticide before they enter trays.

Green Peach Aphids

Green peach aphids can begin to build up when covers are removed or sides are opened to let plants begin to harden off before transplanting. Infestations start as winged aphids that settle on plants and begin to deposit small numbers of live young. The initial infestation consists of a few aphids on scattered plants, but these insects are fast reproducers and numbers can increase rapidly.

Since aphids are sap feeders, there are no holes in the leaves or distinct symptoms to attract attention. Begin checking random trays for aphids about seven to 10 days after plants are uncovered and continue to check a few trays each week until transplant time. Look on the underside of leaves for colonies.

Acephate (Orthene, etc.) can be used for aphid control in greenhouses and outdoor float systems if transplant is greater than five days away. Catch infestations before they become too large to control effectively and direct sprays to the underside of the leaves. In situations where aphid infestations develop within five days of transplant and tray drench applications of imidacloprid are planned, this treatment can be applied and will control aphids prior to transplant. Imidacloprid should not be applied to plants in the greenhouse more than five days before transplant.

Thrips

Thrips are slender, tiny (0.04 inch), light brown to black insects. They feed by rasping the plant leaf surface and sucking up the exuding sap. Heavily infested leaves have a speckled or silvery appearance. Thrips feeding can damage the growing point and cause stunted, unthrifty plants.

Thrips infestations are rare in outdoor float systems but could be a significant problem in greenhouse systems where at least some plants are kept year-round. They can be carried into the greenhouse on contaminated plant material or fly in during the summer and continue to breed throughout the winter.

Blue sticky cards, available from greenhouse suppliers, can be used to monitor thrips and to assess control efforts. Control of established infestations is difficult and usually requires several insecticidal sprays at regular intervals.

Use screens on ventilators, inspect new material entering the greenhouse, and control weeds in the greenhouse to prevent and manage thrips.

Management of Diseases

General Information

The float system offers a number of advantages for growing tobacco transplants, but also creates ideal conditions for some important diseases. High moisture levels and high plant populations favor infection of roots and leaves by a number of plant pathogens. Prevention is the most important part of disease management in tobacco float beds.

The major diseases encountered in production of transplants in the float system are *Pythium* root rot, *Rhizoctonia* stem rot and target spot, Sclerotinia collar rot, and black leg or bacterial soft rot. Less common are anthracnose, damping-off (*Pythium* and *Rhizoctonia*), Botrytis gray mold, angular leaf spot, and virus diseases (such as tobacco mosaic). The following is a summary of recommended practices for the control of diseases commonly encountered in the float system. Lists of recommended fungicides (Table 4) and relative effectiveness of cultural and chemical practices against common diseases (Table 5) have been included.

Develop an Integrated Plan to Manage Diseases

Disease-free transplants pay dividends over the course of the growing season because they are more vigorous and less susceptible to attack by pathogens in the field. Use a strategy that integrates management of the environment, sanitation, and fungicides to get the best possible control of diseases in the float system and produce the best transplants that you can. While it may not be possible to avoid diseases completely, integrated management practices will reduce the impact of diseases in the float system greatly.

Exclude Pathogens from Transplant Facilities

To avoid the introduction of plant pathogens into the float system, consider the following:

- Use well or city water to fill float beds. Surface waters (ponds, creeks, rivers) may harbor pathogens, such as *Pythium*.
- Keep soil and surface water out of float bays. Soil and surface water are key sources of *Pythium*, *Rhizoctonia*, and other plant pathogens. Cover dirt walkways with landscape cloth, gravel, or concrete. Keep trays out of contact with soil when removing them from float beds.
- Use new plastic liners for float beds each year, and avoid introducing natural soil into the bed by removing shoes before walking on new liners.

Table 4. Guide to chemicals available for control of tobacco diseases 2018—transplant production.

Product(s) and (FRAC Code)	Product Rate Per Application[a]	Product Rate Per Season	Target Diseases	Label Notes
Agricultural Streptomycin (25) (Agri-Mycin 17, Firewall, Harbour)	100-200 ppm (1-2 tsp/gal H_2O)	no limit	angular leaf spot wildfire blue mold	Apply in 3-5 gal/1,000 sq ft. Begin when plants are dime-sized or larger.
Aliette WDG (P7)	0.5 lb/50 gal H_2O	1.2 lb per 1,000 sq ft	blue mold	Apply 3 gal of solution per 1,000 sq ft on small plants; increase to a maximum of 12 gal as plants grow.
Mancozeb (M3) (Manzate ProStick [CT, SC,OH, KY,NC,TN] or Penncozeb [VA])	0.5 lb/100 gal H_2O	no limit	blue mold anthracnose damping-off	Apply 3-12 gal/1,000 sq. ft. as a fine spray. Begin when plants are dime-sized or larger.
Milk: Whole/Skim	5 gal/100 gal H_2O	no limit	tobacco mosaic virus (plant-to-plant spread)	Apply to plants at least 24 h prior to handling. Mix will treat 100 sq yd.
Milk: Dry	5 lb/100 gal H_2O			
Quadris (11)	0.14 fl oz (4 ml)/1,000 sq ft	0.14 fl oz (4 ml)/1,000 sq ft	target spot	Only one application prior to transplanting.
Terramaster 4EC (14)	Preventive: 0.7-1.0 fl oz/100 gal H_2O Curative: 1.0-1.4 fl oz/100 gal H_2O	3.8 fl oz	damping-off (*Pythium* spp.) root rot (*Pythium* spp.)	For prevention, apply to float-bed water at 2-3 weeks after seeding. Additional applications can be made at 3-week intervalsThe curative rates can begin no sooner than 3 weeks after seeding. Apply no later than 5 days before transplanting.
Oxidate 2.0	Preventative 6 to 24 oz/1000 gal H_2O	no limit	Pythium	Approved for use in organic production, Should be used preventatively.

[a] Rate range of product. In general, use higher rates when disease pressure is high. Refer to product label for application information, restrictions, and warnings.

Table 5. Relative effectiveness of recommended practices for tobacco transplant production as part of an integrated disease management plan.

Recommended Practice	Pythium Root Rot	Pythium Damping-off	Target Spot (Rhizoctonia)	Rhizoctonia Damping-off/Soreshin	Collar Rot (Sclerotinia)	Blue Mold	Black Leg/ Bacterial Soft Rot	Anthracnose	Botrytis Gray Mold	Angular Leaf Spot	Virus Diseases	Algae
Use new/sterilized trays	+++[a]	+++	++	+++	+	-	-	+	-	-	-	+++
Use municipal water to fill bays	++	++	+	+	-	-	+	-	-	-	-	++
Sanitize equipment, shoes, hands, etc.	++	++	+	+	-	-	++	+	+	-	+++	-
Avoid contact of trays with soil	+++	+++	++	++	-	-	+	+	+	-	-	+
Maintain air movement	-	+	++	+	++	++	++	++	++	++	-	-
Fungicides[b]	+++	+++	+++	++	-	++	+	++	+	+	-	+
Maintain proper fertility[c]	+	++	+++	+	++	+	+++	+	+	+	-	+++
Temperature control	+	+	++	+	+	+	++	++	+	+	-	+
Minimize splashing	-	+	++	+	-	-	++	+++	+	++	-	-
Proper clipping[d]	-	-	++	+	++	+	++	++	+	+	-	-
Avoid buildup of leaf clippings in trays	-	+	+	++	++	-	++	+	++	-	-	-
Dispose of diseased plants properly	-	-	+	+	++	++	++	+	+	+	-	-
Weed control in/around float system	-	-	+	+	+	-	++	++	+	++	++	-
Insect control	-	-	-	-	-	-	+	+	+	-	++	+
Avoid out-of-state transplants	-	-	-	-	-	+++	-	-	-	-	+	-
Avoid tobacco use when handling plants	-	-	-	-	-	-	-	-	-	-	++	-

[a] - = no effect on disease management, + = minimally effective, ++ = moderately effective, +++ = highly effective.
[b] Preventive applications only (made before symptoms appear).
[c] Based upon a recommended range of 75-100 ppm of nitrogen.
[d] Clip using a well-sharpened blade, low blade speed, and remove no more than ½" of foliar tissue at a time, all under conditions that promote rapid drying of foliage.

- Control weeds in and around greenhouses and outdoor float beds. Weeds interfere with ventilation and also harbor pathogens and insects.
- If using plugs, grow your own or purchase from a local supplier. Don't buy plugs or plants from sources in the Deep South to avoid the possible introduction of the blue mold pathogen.
- Don't grow vegetables or ornamentals in the same facilities where tobacco seedlings are being produced. Vegetables and ornamentals may harbor pathogens that can infect tobacco.

Make Sanitation a Routine Practice

Good sanitary practices during transplant production reduce the chances of introducing pathogens or carrying them over between growing seasons. Recommended sanitary practices include:

- Sanitize old trays or use new trays for each crop of transplants. Discard trays that are more than 3 to 4 years old, as these trays become porous and nearly impossible to sanitize thoroughly. A simple way to label trays by the year purchased is to spray paint a line down the stack of new trays; use a different color each year. See "Tray Sanitation and Care" in this article for details.
- Thoroughly clean plant residue from mower blades and other equipment, then sanitize with a solution of 1 part bleach to 9 parts water. Bleach solutions may be inactivated by excess plant material.
- Remove diseased plants before clipping to avoid spread to healthy seedlings.
- Promptly dispose of diseased or unused plants. Discard these plants at least 100 yards downwind from the transplant facility to minimize movement of pathogens from cull piles back into the float system.
- Clip properly to avoid buildup of leaf matter in trays, and remove excess material that collects in trays. Diseases such as black leg and collar rot often begin on debris and then spread to healthy seedlings.
- Wash hands and sanitize shoes before entering the transplant facility or handling plants.
- Avoid the use of tobacco products when working with tobacco seedlings.

Create an Unfavorable Environment for Plant Pathogens

Management of temperature and humidity are critical factors in the management of float bed diseases. Long periods of leaf wetness favor many pathogens, so keeping foliage as dry as possible should be a major goal. Take steps to manage soil moisture. Although transplants are floating on water continuously during the production cycle, plugs in properly filled trays are not waterlogged. Waterlogging of cells can lead to the development of disease problems, particularly as temperatures rise. The environment in float systems can be made less favorable for disease by employing the following guidelines:

- Maintain good air movement around plants through the use of side vents and fans.
- After the first clipping, keep water levels high enough for float trays to clear the side boards of the bays, allowing for better air movement.
- Avoid overhead irrigation and minimize potential for water splash between trays. Condensation that forms on cool nights can drip onto plants, wetting foliage and spreading pathogens.
- Avoid temperature extremes. Cool temperatures favor diseases like collar rot, while warmer temperatures favor target spot and black leg (bacterial soft rot).
- Don't over-pack trays with media, and dispose of trays more than 3 to 4 years old. Over-packed trays tend to waterlog easily, as do older trays, and disease risk increases in these cases.

Optimize Production Conditions

Improper fertilization or clipping can increase the likelihood of disease, particularly for pathogens that are common in the environment, such as *Pythium* or black leg bacteria. The following practices can help keep slow the spread of plant diseases.

- Keep nitrogen levels in float beds between 75 and 125 ppm. Seedlings are more susceptible to target spot when nitrogen drops below 50 ppm, and problems with black leg (bacterial soft rot) are most common when nitrogen levels exceed 150 ppm for extended periods. Excess nitrogen also promotes rapid growth that takes longer to dry and is more susceptible to disease. Over-fertilized plants also need to be clipped more frequently, increasing the risk of certain diseases.
- Clip properly (see "Clipping," page 16) to reduce the volume of clippings. Make sure the mower's blade is sharp to promote rapid healing of wounds. Clip plants when leaves are dry to reduce the risk of spreading disease.

Apply Fungicides Wisely

A small number of fungicides are labeled for use on tobacco in the float system. These products are aimed at *Pythium* root rot, blue mold, anthracnose, damping-off, and target spot. The remaining diseases can be managed only by cultural practices.

Fungicides need to be applied in a timely manner to get the best disease control in the float system. Products labeled for use in the float system and their rates are listed in Table 4. Do not use products that are not labeled for tobacco, or those that prohibit use in greenhouses. Guidelines for using fungicides against important diseases are listed below.

Pythium Root Rot

- Preventive applications of Terramaster EC generally give better control of disease than curative applications and tend to cause less injury to seedlings.
- For disease prevention, apply Terramaster EC (1 fl oz/100 gal of float water) when tobacco roots first emerge from the bottoms of trays (approximately two to three weeks after seeding, or longer depending on water temperature).
- Single preventive applications of Terramaster are usually adequate if new or properly sanitized trays are used. Where disease risk is higher, supplemental applications can be made up to five days before transplanting. The interval between applications is three weeks, and use no more than 3.8 fl oz/100 gal of float water per crop of transplants.
- Curative treatments can be made by treating float water with Terramaster EC at 1 to 1.4 fl oz/100 gal, beginning at the first appearance of symptoms. Do not make a curative treatment earlier than three weeks after seeding.

- Curative treatments do not eradicate *Pythium* from the float system, and retreatment is occasionally required. Follow-up treatments can be made as described for the preventive schedule. Seasonal limits and timing between treatment and transplanting are the same as for the preventive schedule.
- Always mix Terramaster EC thoroughly in float water to avoid plant injury and to achieve the best control of *Pythium* root rot.

Plant injury is a concern with Terramaster EC, but serious problems can be avoided by careful mixing and timely application. Terramaster EC will burn the roots of tobacco seedlings, but plants quickly recover. Stress from root burn is minimized if Terramaster EC is applied when roots first enter the float water and is greatest when the fungicide is applied to seedlings with extensive root systems. Severe root burn can lead to stunting and delayed development of seedlings—reason enough to begin applications of Terramaster EC early.

- Oxidate 2.0 is an organic approved option labeled for use in tobacco float beds for management of multiple diseases including *Pythium*.
- According to label directions Oxidate 2.0 should be used preventatively at a rate of 6 to 24 oz/1000 gal of water.
- Float water must be treated on a regular basis with Oxidate 2.0 to maintain a residual 100 ppm concentration.
- Preliminary studies indicated reasonable control of *Pythium* with new trays in float water inoculated at a single time with *Pythium*
- The long term efficacy of Oxidate 2.0 in a float system with old trays and continued disease pressure has not been adequately studied.

Target Spot, Rhizoctonia Damping Off, and Blue Mold

- Check float beds regularly for problems, and treat when symptoms of disease are first observed if a routine fungicide program is not in place.
- Fungicides containing mancozeb (Manzate Pro-Stick in CT, PA, SC, NC, OH, TN and KY; Penncozeb in CT, VA) can be used for prevention of target spot. Routine application is recommended for facilities with a history of target spot. Regular applications of mancozeb also offer protection against blue mold. Apply in enough water to achieve coverage of leaves and stems. Avoid treating plants smaller than the size of a dime due to risk of plant injury.
- Quadris Flowable fungicide is labeled for use on tobacco transplants, but only for the control of target spot. This fungicide can be used only once before transplanting, and growers must have a copy of the Special Local Need label (labeled in MD, SC, KY, NC, IN, GA, VA, PA and TN) in their possession at the time of treatment. Apply at a rate of 4 ml/1000 sq. ft (just under 1 tsp), using 5 gal/1000 sq. ft to achieve good coverage. For best results, make this application after the first or second clipping, or when symptoms are first observed. If needed, mancozeb can be used prior to and after treatment with Quadris. The application of Quadris in the greenhouse counts against the total number of applications allowed for the crop once in the field.
- If blue mold threatens or is found in your area, treat with mancozeb or Aliette WDG. Consult your local Cooperative Extension agent or news outlets to learn about the current status of blue mold.

Field Selection and Soil Preparation

Bob Pearce, Edwin Ritchey, and David Reed

Field Site Selection

Ideally, sites for tobacco production should be chosen two to three years in advance of planting, which allows for observation of any problems, such as poor drainage, low fertility or soil pH, and specific types of weeds common in a field. Several factors need to be considered when selecting sites for tobacco, including soil properties, rotational requirements, conservation compliance requirements, herbicide carryover or drift potential and proximity to curing facilities or irrigation.

The roots of a tobacco plant are very sensitive to the aeration conditions in the soil. In saturated soils, tobacco roots begin to die within six to eight hours, with significant root loss occurring in as little as 12 to 24 hours. This sensitivity to aeration conditions is why tobacco plants wilt or "flop" after heavy rainfall events. Tobacco grows best in soils with good internal drainage, which helps keep excess water away from the roots. Of course, tobacco also needs water to grow, and a soil with a good water holding capacity is an advantage during the short-term dry spells that are common during summers in the regions where burley and dark tobacco are grown. The best soils for burley and dark tobacco production tend to be well-structured silt loam or silty clay loam soils. Soils with brown or red color are well aerated most of the year and indicate good internal soil drainage. Soils that contain grey or mottled colors are saturated a substantial amount of the year and indicate poor or somewhat poor internal drainage.

Cover Crops

The benefits of using winter cover crops are well-documented. Winter cover crops protect the soil from erosion losses, scavenge leftover nutrients from the soil, and add organic matter to soil when they are plowed under or killed in the spring. Winter cereal grains, such as wheat and rye, are the most commonly used cover crops in tobacco production. These grains, when planted in September or October, make good growth by early winter to help reduce soil erosion, scavenge excess nutrients, and grow very rapidly in spring as the weather warms. Winter grains should be plowed under or killed in early spring no later than when they are heading. Waiting too long can result in nutrients being tied up by the cover crop, significant reductions in soil moisture during dry springs, and, in some cases, organic matter toxicity to the tobacco crop. Organic matter toxicity can occur when a heavy cover crop is plowed under just before transplanting. The breakdown of the cover crop reduces oxygen in the root zone and may result in the production of organic

compounds and/or nitrite that are toxic to roots. Affected tobacco plants appear yellow and stunted but usually recover in two to three weeks.

Winter legumes, such as vetch or crimson clover, may also be used as cover crops, either alone or in combination with a winter cereal. Alone they do not produce as much growth in the fall compared to winter annual cereals when planted at typical cover crop planting times. However, legumes have the potential to fix nitrogen from the atmosphere and supply additional nitrogen to the crop that will follow them. In practice, the amount of nitrogen fixed by legume cover crops is limited due to the relatively short period of growth in the spring prior to termination.

Brassica cover crops including oilseed radishes, mustards, and turnips can also be used as cover crops for tobacco fields. There are several brassica species that have been developed specifically for cover crops and provide similar benefits to winter cereal grains. In addition to these benefits, limited data suggests that some of the brassica cover crops may help to reduce mild to moderate soil compaction. One limitation of brassica cover crops is that many species are prone to winter kill, so including a winter cereal with the brassica is recommended. Furthermore, like the legumes (vetch in particular), certain brassicas can become a nuisance weed in the following tobacco crop if are allowed to go to seed.

Crop Rotation

The benefit of crop rotation for reducing certain diseases is well known (see Disease Management, page 33); however, rotation also has significant agronomic benefits. A good rotation scheme is a key element to maintaining the long-term productivity of fields used for tobacco production. Continuous and intensive tillage from the production of tobacco can result in losses of soil organic matter, weakened soil structure, and severe soil erosion. All of these factors lead to declining productivity over time. In some cases, rotation may be necessary for growers who are required to have a conservation compliance plan to remain eligible for government farm programs. Even though tobacco itself is no longer covered under any federal farm programs, a grower who is out of compliance with their conservation plan on any part of a covered farm risks losing benefits for all commodities.

A good long term rotation for maximum agronomic benefits would be one in which tobacco is grown on a specific site for no more than two years in a row, after which a sod or sod/legume crop is planted and maintained for at least four years before returning to tobacco production. The advantage of this rotation is that the long period in a sod crop helps restore the organic matter and soil structure lost during tobacco production. Unfortunately, many tobacco growers do not have sufficient land resources to maintain a rotation of this length. Shorter rotations away from tobacco are still very beneficial from a disease management standpoint and slow the degradation of soil structure compared to continuous tobacco production. Some rotation to a sod or hay crop, even if it is of short duration, is better than no rotation at all.

Herbicide carryover has become an increasing concern for tobacco in rotation with pasture/hay fields in recent years due to the use of pasture herbicides containing the active ingredients of picloram or aminopyralid. Brand names of these herbicides include Chaparral, Grazon, Surmount, Milestone, and Forefront. Sensitive broadleaf crops such as tobacco should not be planted for **at least 3 years** after aminopyralid has been applied and an adequately sensitive field bioassay shows that the level of aminopyralid present in the soil will not affect the crop. For picloram, the period of time needed before planting tobacco is not well-defined. Products containing picloram should never be applied to land that is intended to be a part of a tobacco rotation, and tobacco should not be planted in a field with any known history of picloram use until test plants have been grown in the soil for a few weeks and observed for injury symptoms. See the label for other restrictions and information.

Rotation to other row crops, such as corn or soybean, is also beneficial to tobacco, but less so than a rotation which includes sod crops. Rotations in which the rotational row crops are grown using conservation tillage practices are of the most benefit. Tobacco growers may also want to consider some form of conservation tillage for tobacco as well to help maintain long term soil productivity. In row crop rotations, precautions should be observed to minimize the potential carryover of herbicides and adhere to rotational guidelines on pesticide labels.

The proximity of tobacco fields to curing facilities is an obvious but often overlooked selection criterion. A large amount of time and money can be wasted transporting tobacco (and often crews) between the field and the curing barn. Consider placing new barns in an area that can be accessed from several tobacco production fields so that a good plan of rotation can be established.

Conventional Tillage

The typical tillage scenario for tobacco production usually involves moldboard plowing in late winter, often followed by smoothing with a heavy drag and two to four diskings prior to transplanting. Some growers may use a power tiller in place of the disk to break up clods and produce a smooth seedbed. After transplanting, many growers continue to till the soil with two or three cultivation operations. Compared to most other crops currently grown in the southeastern US, the level of tillage used for tobacco is intense. Tillage in tobacco production is useful to help control weeds, incorporate cover crops, reduce shallow soil compaction, improve aeration, and incorporate fertilizers and chemicals. However, excessive tillage or tillage under the wrong conditions can create compaction and lead to soil loss due to erosion.

All soils consist of the solid particles and the gaps or spaces, called pores, between the solids. In an un-compacted soil, the pores make up about 50% of the soil volume and are well distributed between small and large pores. Smaller pores are generally filled with water, while the large pores may fill with water during a rain event but quickly drain and are usually filled with air. This balance of air and water is beneficial for root growth. When a soil becomes compacted there is a significant reduction in pore volume and a loss of pore space, with the large pores being lost more readily than the small pores. Compaction creates a physical barrier that limits root growth and water drainage.

Intense tillage contributes to soil compaction in at least two ways. Tillage destroys soil organic matter and weakens soil structure, making the soil less able to resist the physical forces

of compaction. The more intense the tillage or the longer tillage has been practiced, the weaker the soil structure will become. Tillage implements such as plows and disks exert tremendous pressures on the soil at points of contact. So even though tillage may seem to fluff up the soil at the surface, often compaction is taking place at the bottom of the tillage implement. Power tillers can exert tremendous pressure at the point where the tines contact the soil, resulting in compaction. The use of these implements to increase drying of wet soils before transplanting tends to compound the problem and may lead to poor plant performance throughout the season. Power tillers may do more damage to soil structure in one pass than several diskings. Tillage-induced compaction generally occurs from four to eight inches below the surface, depending upon the tillage implement used. Silt loam soils are most susceptible to tillage-induced compaction when tilled at soil moisture contents of about 15-25% or near field capacity. Field capacity is the soil moisture content that free water drainage ceases and occurs about two days after a "normal" rain.

Naturally occurring compacted zones, known as fragipans, are present in some soils. Fragipans are more common in Western Kentucky and Western Tennessee than the central and eastern parts of the states. These compacted areas are typically found deeper than tillage compaction and may range in depth from 12 to 30 inches or more. Fragipans are responsible for poor water drainage in the spring and limited plant-available water during the summer. The degree to which they adversely affect tobacco production depends upon the fragipan depth and severity of compaction.

The aboveground signs of a soil compaction problem are difficult to recognize and are often mistaken for other problems. These signs can include stunted growth, multiple nutrient deficiencies, and reduced drought tolerance due to limited root growth. If soil compaction is suspected, the best way to identify it is by digging up and examining roots. The root system of a normal tobacco plant should be roughly bowl-shaped with a horizontal spread approximately two to three inches wider than the leaf spread. The presence of flat spots or areas with little or no roots suggests that compaction may be a problem (Figure 1).

Compaction in fields may also be characterized with the use of a soil probe, tiling probe, or a penetrometer, a device specifically designed to measure compaction. The penetrometer is a pointed rod with a tee-handle attached and a gauge for reading the pressure required to push the rod into the soil. It is important to note the depth at which the compacted layer begins and the overall thickness of the compacted layer so that appropriate remediation procedures can be planned.

The best management for dealing with tillage-induced compaction is to avoid it. This means not working ground that is too wet and avoiding overworking. The potential for compaction can be lessened by practicing rotation, which adds organic matter to the soil and strengthens soil structure. Using less intensive tillage implements like chisel plows and field cultivators can also help. Deep tillage (subsoiling) to break up compaction should only be used when the compacted layer has been confirmed and should only be used to the depth of that layer. Deep tillage to depths greater than the compacted layer does little to improve plant growth and results in excessive fuel use. Further, deep tillage should be done when the soil is dry enough for the soil to fracture, typically in the fall. If deep tillage is conducted when the soil is too wet, the soil will not properly fracture and can lead to increased soil compaction due to the heavy weight of the machinery typically used for this operation.

Shallow in-row tillage has been shown to be an effective means of reducing the negative effects of compaction on tobacco in some Western Kentucky soils (Table 1). In these studies, the compacted layer was measured using a penetrometer, and the depth and thickness of the layer were determined. The degree of compaction was characterized as slight, moderate, or severe. In all cases where moderate or severe compaction existed there was a positive benefit from in-row sub-soiling. Where compaction was only slight, no benefit from sub-soiling was observed. In-row sub-soiling is a relatively easy and inexpensive way to deal with shallow compaction in tobacco, as long as the tillage is done when the soil is relatively dry. In-row sub-soiling under wet soil conditions can lead to the development of an air cavity under the roots of young transplants.

Cultivation of established tobacco can be used to control weeds, but must be conducted at the appropriate time and for the appropriate reason. Before the widespread use of preplant

Figure 1. Tobacco root system showing distinct signs of soil compaction. Note the flattened appearance of the bottom, protrusion of the transplant root ball, and limited new root growth from the lower portion of the root ball.

Table 1. Effect of in-row sub-soiling on the yield of burley and dark tobacco.

		Conventional	Sub-soiled
Soil Type	**Compaction**	**Cured Leaf Yield (lb/A)**	
Loring	Moderate	2626	3333
Vicksburg	Moderate	1924	2448
Grenada	Moderate	1473	1691
Loring	Severe	2463	3450
Grenada	Slight	2755	2799
Tilsit	Slight-Mod	2012	2158
Loring	Moderate	2365	2679
Avg.		2200 A*	2605 B

* Means followed by the same letter are not significantly different at p = 10%.
Data from Lloyd Murdock and others, 1986.

chemicals for weed control, it was not uncommon for a tobacco producer to cultivate a crop five or more times during a season. Some producers were so accustomed to cultivating that they just made it a routine management practice in their operation. Cultivation should only be used in certain situations, mainly to control weeds. Other reasons for cultivation would include: incorporation of fungicides to control diseases such as black shank; incorporation of urea-based fertilizers to reduce volatilization losses of N; and to push soil around the base of plants to help prevent ground suckers or lodging with tall or "leggy" plants.

When it is necessary to cultivate, the cultivators should be set as shallow as possible but still remove weeds or disrupt the soil-to-root contact of the weeds. Cultivating deeper than necessary will pull moisture from depth to the soil surface and cause the soil to dry out faster. Cultivating too close to the plant will prune many roots or can physically "shake" the plants, disrupting the soil-to-root contact. Depending on the amount of roots pruned or the extent of "shaking", plants can either be stunted, or in severe cases, killed.

There are other factors that should be considered prior to cultivating. Two common soil-borne diseases in tobacco are black shank and Fusarium wilt (see Disease Management, page 33). Both of these diseases can be moved within and between fields on equipment. Another factor that one should consider prior to cultivation is weed control. A soil-applied herbicide will form a barrier in the soil that prevents weed seed from germinating. Cultivating can disrupt this barrier and actually allow weed seed to germinate that might not have germinated if the ground was not disturbed. A series of field trials conducted in Central Kentucky in 2008 to 2010 showed that cultivation was not necessary to produce good burley tobacco yields when adequate weed control was achieved with preplant herbicides.

Throughout the burley and dark tobacco growing regions, tobacco is grown on sloping fields, much of it on slopes of 6% or more. When these fields are tilled, they are extremely vulnerable to erosion losses for at least two to three months during the spring and early summer when strong storms with heavy rainfall are common. Gullies to the depth of plowing are a common site in tobacco fields (Figure 2). Losses can be minimized by waiting until just before transplanting to do secondary tillage operations and by planting rows of tobacco across the slope rather than up and down the slope. Leaving the tractor tracks in place until the first cultivation can increase surface roughness, thus lessening the velocity of water runoff and soil erosion. Alternatively, some growers may want to consider some form of conservation tillage.

Conservation Tillage

The adoption of conservation tillage methods for tobacco production has been relatively slow compared to common row crops such as corn or soybean. Traditionally, tobacco growers have used intensive tillage to care for this high value crop, and many still believe that tobacco must be cultivated routinely for good growth. There are other reasons that tobacco growers have been slow to adopt conservation tillage, including a lack of appropriate transplanters, limited weed control options, and uncertainty over the future levels of tobacco production. Some of these issues have been partially addressed such that some growers now consider conservation tillage to be a feasible option for tobacco production.

Table 2. Burley yields by tillage system, Greeneville and Springfield, TN, 2009.

Tillage System	Greeneville	Springfield
	Cured Leaf Yield (lb/A)	
No-till	2864	1854 a*
Narrow Chisel Strip-Till	2912	2241 b
KMC Strip-Till	2983	2236 b
Rototill Strip	3012	2282 b
KMC Strip plus Rototill	2968	2256 b
Chisel Plow-disk	3054	2128 b

* Means followed by the same letter are not significantly different at P= 10%. No differences in yield at Greeneville.

The principal advantage of conservation tillage is a reduction in soil loss caused by erosion; however, there are other advantages for the grower as well. The mulch layer on the soil holds in moisture and may help reduce stress during periods of short-term drought. Additionally, the mulch layer may help to keep the leaf cleaner by reducing mud splash on cut tobacco during late-season rain storms. Fewer heavy tillage trips means less time and less fuel use than with conventional tobacco production. No-till or strip-till fields may also have better trafficability in wetter times, allowing more timely application of needed fungicides, insecticides, or sucker control materials during rainy periods.

Conservation tillage includes no-till, in which the soil is not worked prior to transplanting; minimum-till, in which the soil is worked in such a way as to leave 30 to 50% of the residue on the surface; and strip-till, in which a 10- to 12-inch-wide band

Figure 2. Severe gully erosion in conventionally prepared tobacco field.

is tilled before transplanting. Each system has its advantages and disadvantages that the tobacco grower must consider.

No-till tobacco is really a form of strip-tillage in which the tillage and transplanting functions occur in one operation. Considerable modifications must be made to the transplanter for successful no-till planting. Figure 3 shows an example of the modifications required. At a minimum, a no-till transplanter needs a wavy (fluted) coulter in front to cut residue, a subsurface tillage shank to till the root zone and pull the unit into the ground, and modified press wheels to close the planting trench. Some growers have added row cleaners to assist in moving residue away from the row, allowing easier planting. Costs for modifying conventional transplanters range from $300 to $600 per row, depending on how much fabrication growers are able to do themselves. No-till ready transplanters are currently available from some manufacturers.

No-till tobacco works best on medium-textured soil (silt loam to sandy loams). No-till tobacco can be produced in clay ground, but the grower must be patient and wait for the soil to dry sufficiently before transplanting. One of the persistent myths about no-till tobacco is that it can be planted when conventionally prepared ground is still too wet. In fact, experience has shown that it takes two or three days longer for no-till sites to dry out prior to setting. Even though the ground may be firm enough to support equipment, the mulch layer slows the drying rate at the surface. Transplanting in ground that is too wet can lead to compaction of the trench sidewall, which restricts root growth and may suppress growth and yield potential.

Minimum or strip-till may be better on heavy clay ground, since some of the surface residue is incorporated, allowing the soil to warm up and dry out quicker. These methods require additional tillage passes, leaving the soil more vulnerable to erosion than no-till. Growers using strip tillage are able to transplant using their normal transplanter. However, they often have one or more modified tillage implements matched to the row spacing and number of rows of the transplanter to prepare the 10- to 12-inch-wide planting band.

In conservation tillage studies conducted in Tennessee during the 2009 growing season, no-till and strip-till yields compared favorably to a chisel plow-disk conventional tillage system at the Greeneville Research and Education Center on a deep, well-drained loam soil (Table 2). No-till tobacco yielded significantly less than strip-till and conventional tillage on a moderately well-drained silt loam soil with a fragipan at the Highland Rim Research and Education Center.

A good cover crop or previous crop residue is an essential part of successful conservation tillage tobacco production. The cover crop or residue helps to reduce soil erosion losses and conserve water in the soil, much like mulch in the garden. Tobacco growers have been successful planting no-till tobacco in winter grain cover crops, sod, and row crop residues.

One of the keys to success when planting no-till tobacco into a small grain is timing the kill of the cover crop. The initial burndown of winter small grains should be made when the cover is approximately 6 to 8 inches tall, which allows a sufficient buildup of residue while limiting the production of straw that complicates transplanting. Research has shown that tobacco transplants grew better and yielded more when the cover crop was killed at least 30 days prior to transplanting. The closer to transplanting the cover crop is terminated, the more likely there will be delays in early-season tobacco growth (Figure 4).

Figure 3. Modifications to a transplanter for no-till transplanting of tobacco.

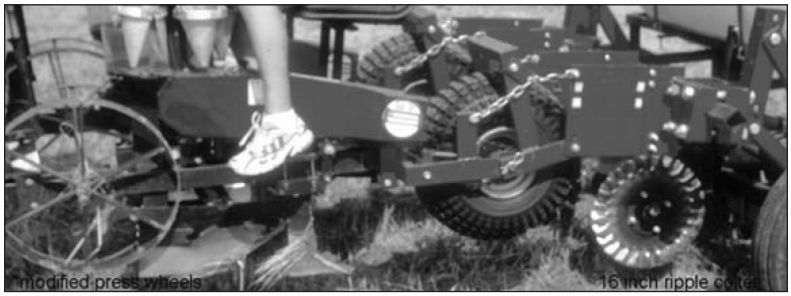
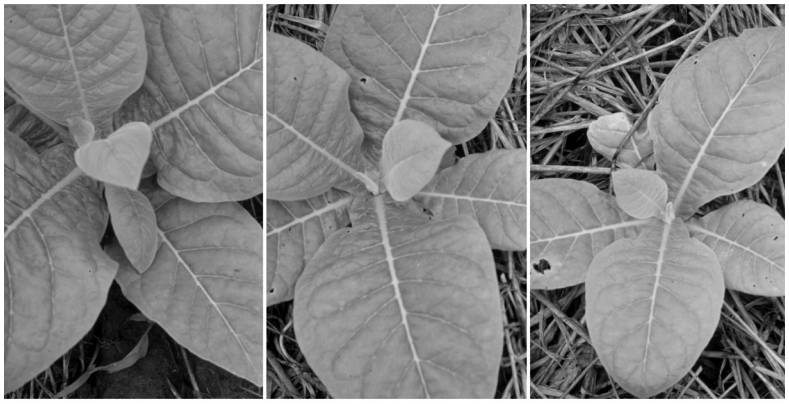


Figure 4. Effect of time of cover crop termination (days before transplanting) on early-season tobacco growth.



30 days 15 days 1 day

When conservation tillage follows a sod crop, it is best to burn down the sod in the late fall. If erosion is a concern due to steep land and/or a thin cover of old sod, a no-till cover crop can be planted in the fall to be burned down the following spring. If burndown occurs in the spring, it should be at least four to six weeks prior to transplanting. This allows sufficient time for the root mass to break down so that the soil will crumble and fill in around the plant root ball. Research at the University of Tennessee has shown advantages for fall burndown. Elimination of a sod that includes alfalfa can be particularly difficult due to the persistence of the alfalfa crowns. To eliminate alfalfa stands to prepare for no-till tobacco, an application of burndown in the fall and a follow-up application in the spring may be required. Even then, some volunteer alfalfa may be present in no-till tobacco fields.

Weed Control for Conservation Tillage

General weed control for tobacco production is covered in the Weed Management chapter in this guide, but some recommendations specific to conservation tillage are covered here. Because no-till tobacco is a relatively small use crop,

there are very few products labeled specifically for this use. Glyphosate-containing products do not include tobacco as a crop listed on the label. Therefore, it cannot be applied on tobacco fields unless an interval of 30 to 35 days occurs before transplanting. Gramoxone SL 2.0 (paraquat) has EPA approval for use on no-till tobacco in specific states (KY, TN, and NC). Growers must take care to obtain a copy of the supplemental label for this use, as it does not appear on the label normally included with the product.

There are labeled weed control products that work well for no-till tobacco, but "rescue" options are very limited, so it is best to choose sites with as low of a weed potential as possible. Winter pastures, feed lot areas, and areas with sparse cover often make poor sites for conservation tillage tobacco due to large amounts of weed seed in the soil and/or established populations of perennial weeds. Perennial weeds and vines should be controlled during the rotation prior to growing no-till tobacco.

Sulfentrazone (Spartan or generic) should be a part of any weed control program for conservation-till tobacco. Research has demonstrated that this product provides more consistent control in the absence of tillage than other herbicide option. Clomazone (Command) can be tank-mixed with sulfentrazone for improved control of certain weeds and grasses. However, the most consistent control has been achieved by applying sulfentrazone seven to 10 days prior to transplanting and then making an application of clomazone within seven days after transplanting. The post-transplant application helps to control weeds in the strips of soil disturbed by the transplanting operation. For all herbicides, the highest labeled rate for the soil type is recommended when used in conservation tillage (see Weed Management, page 27, for labeled rates of herbicides.)

Marestail has become a problem in recent years in some fields of conservation tillage tobacco in Kentucky and Tennessee. Options for controlling this troublesome weed in tobacco are very limited, so a proactive approach is a must. There are some herbicides labelled for other crops that might help control troublesome tobacco weeds during rotational intervals in tobacco fields. The marestail populations found in many fields are not well controlled by glyphosate applications. Preliminary studies have shown that well timed burndown applications of paraquat are effective in control of young emerged marestail. However, since marestail seedlings emerge over a period of weeks or months, multiple applications may be required and full control may still not be achieved. Flumioxazin (eg. Valor SX) is approved for use in fall and spring burndown programs for tobacco. For spring burndown applications, the product may be applied at 1 to 2 oz/A when applied with labelled burndown herbicides such as paraquat. A minimum of 30 days must pass with at least 1 inch of rainfall or irrigation occurring before tobacco can be transplanted. The flumioxazin product labels indicate residual control of marestail, but these claims have not been verified by University trials on conservation tillage tobacco.

Sethoxydim (Poast) can be used over tobacco for control of annual and perennial grasses, including johnsongrass. In cases where weed control has been poor due to environmental conditions, some growers have used mechanical means, such as lawn mowers and cultivators, to control weeds in conservation-till tobacco.

Weed Management

J.D. Green, Neil Rhodes, Chuck Johnson, and Matthew Vann

Weeds can impact tobacco production by reducing yield, interfering with crop harvest, and contaminating cured leaf as Non-Tobacco Related Material (NTRM). Many of the common weed problems in tobacco are summer annuals such as foxtails, pigweeds, lambsquarters, and annual morningglories. In addition, some perennials such as johnsongrass, honeyvine milkweed, and yellow nutsedge can be particularly troublesome in some tobacco fields. In locations where troublesome weeds are difficult to control it may become necessary to choose an alternative field site to grow tobacco. Table 1 is a guide to the

Table 1. Guide to the relative response of weeds to herbicides.[1]

	Barnyardgrass	Braodleaf Signalgrass	Crabgrass	Fall Panicum	Foxtails	Johnsongrass (seedling)	Johnsongrass (rhizome)	Yellow Nutsedge	Black Nightshade	Cocklebur	Galinsoga, Hairy	Jimsonweed	Lambsquarters	Morningglory	Pigweeds	Prickly Sida	Purslane	Common Ragweed	Ragweed, Giant (Horseweed)	Smartweed	Velvetleaf
Command, etc.	**G**	**G**	**G**	**G**	**G**	F	P	P	P	F	F	F	**G**	P	P	**G**	**G**	**G**	F	F	**G**
Devrinol	**G**	**G**	**G**	**G**	**G**	F	P	P	P	N	F	N	F	N	F	P	**G**	F	N	P	P
Prowl, etc.	**G**	**G**	**G**	**G**	**G**	**G**	P	N	N	N	P	N	**G**	P	**G**	P	**G**	P	N	F	F
Spartan, etc.	F	F	F	F	F	P	P	**F-G**	**G**	F	F	**G**	**G**	**G**	**G**	**G**	**G**	P	P	**G**	F
Spartan Charge	F	F	F	F	F	P	P	**F-G**	**G**	F	F	**G**	**G**	**G**	**G**	**G**	**G**	P	P	**G**	F
Spartan + Command	**G**	**G**	**G**	**G**	**G**	F	P	**F-G**	**G**	F	**G**	**G**	**G**	**G**	**G**	**G**	**G**	**G**	F	**G**	**G**
Poast	**G**	**G**	**G**	**G**	**G**	**G**	F	N	N	N	N	N	N	N	N	N	N	N	N	N	N
G = Good F = Fair P = Poor N = None - No Data Available																					

[1] This table should be used only as a guide for comparing the relative effectiveness of herbicides to a particular weed. Under extreme environmental conditions, the herbicide may perform better or worse than indicated in the table. If a grower is getting satisfactory results under their own conditions, products should not necessarily be changed as a result of the information in the table.

relative response of selected weeds to various herbicides available for use in tobacco.

Land preparation practices such as moldboard plowing and disking provide initial weed control by destroying early season weeds that emerge before transplanting. Field cultivation and hand-hoeing are also traditional methods to maintain good weed control post-transplant, but effective herbicide control options decrease the need for mechanical control methods. A foliar burndown herbicide also allows production of tobacco by conservation tillage methods. Specific herbicide options that are currently recommended for use on tobacco fields are discussed in Table 2.

Use of certain herbicides on a previous crop can limit the rotational crops that can be planted in treated fields. For example, when atrazine is applied for weed control in corn during the previous growing season, there is a possibility that tobacco could be injured the year following application. Residual carryover from some pasture or forage crop herbicides can also severely damage tobacco planted in treated fields, sometimes for many years after the original application. Therefore, consult the herbicide labels to determine whether there is a risk to planting tobacco in fields that were used to grow other grain or forage crops. General rotational crop guidelines for herbicides available in grain crops can be found in University of Kentucky Extension bulletin *Weed Control Recommendations for Kentucky Grain Crops* (AGR-6) the University of Tennessee Extension bulletin *Weed Control Manual for Tennessee* (PB 1580), the *North Carolina Agricultural Chemicals Manual*, or the *Virginia Cooperative Extension Pest Management Guide for Field Crops* (456-016).

Be familiar with label guidelines and rotational restrictions when applying tobacco herbicides. Limitations for some rotational crops are highlighted within the remarks for each herbicide listed in Table 2.

Table 2. Herbicides recommended for use in tobacco fields.

Herbicide	Remarks and Limitations
Before Transplanting—Burndown Herbicides for Use in Conservation Tillage	
Gramoxone SL 2.0 2.74 to 3.75 pt/A or **Gramoxone SL 3.0** 1.6 to 2.5 pt/A (*paraquat* 0.6 to 0.94 lb ai/A) + Non-Ionic Surfactant 2 pt/100 gal or Crop Oil Concentrate 1gal/100 gal [Supplemental label for use in KY, TN, and NC only]	**Weeds Controlled:** Annual grasses and broadleaf type weeds that have emerged or for burn-down of cover crops. Apply when weeds and cover crop are actively growing and between 1 to 6 inches in height. Vegetation 6 inches or taller may not be effectively controlled. ***A copy of the supplemental label should be in the hands of the applicator at time of application.*** Certified applicators must successfully complete an EPA-approved training program before mixing, loading, and/or applying paraquat. Apply as a broadcast treatment during the early spring but prior to transplanting tobacco. Use the higher rate on dense populations and/or on larger or harder to control weeds. Weeds and grasses emerging after application will not be controlled. A maximum of 2 applications may be made. Gramoxone may be tank-mixed with other registered tobacco herbicides for improved burndown. Do not graze treated areas or feed treated cover crops to livestock.
Before Transplanting—Soil-applied Herbicides	
Command 3ME 2 to 2.67 pt/A (*clomazone* 0.75 to 1 lb ai/A) Other products containing *clomazone* and labelled for use on tobacco include: **Caravel (3ME), Civic 3ME, Up-Stage 3CS, Vopac 3ME Willowood Clomazone 3ME** [consult specific product labels for application rates, precautions, restrictions etc.]	**Weeds Controlled:** Barnyardgrass, broadleaf signalgrass, crabgrass, fall panicum, foxtails, jimsonweed, lambsquarters, prickly sida, purslane, common ragweed, velvetleaf Apply as a soil-applied treatment prior to transplanting. Off-site movement of spray drift or vapors of clomazone can cause foliar whitening or yellowing of nearby sensitive plants. Consult label for spray drift precautions and required setbacks when applied near sensitive crops and other plants. Tobacco plants growing under stressed conditions (cold/wet weather) may show temporary symptoms of whitening or yellowing. COMMAND and similar products may be tank-mixed with other herbicides registered for use in tobacco to broaden the weed control spectrum or with other tobacco pesticides [consult labels]. Cover crops may be planted anytime, but foliar whitening, yellowing, and/or stand reductions may occur in some areas. Do not graze or harvest for food or feed cover crops planted less than 9 months after treatment. When applied alone, rotational crops that may be planted include soybeans, peppers, or pumpkins anytime; field corn, popcorn, sorghum, cucurbits, or tomatoes (transplanted) after 9 months; sweet corn, cabbage, or wheat after 12 months; and barley, alfalfa, or forage grasses after 16 months following application. See label for rotation guidelines for other crops and when tank-mixed with other herbicides.
Devrinol 50DF 2-4 lb/A or **Devrinol DF-XT** 2-4 lb/A or **Devrinol 2-XT** 2-4 qt/A (*napropamide* 1-2 lb ai/A)	**Weeds Controlled:** Barnyardgrass, broadleaf signalgrass, crabgrass, fall panicum, foxtails, purslane Apply to a weed-free surface before transplanting and incorporate immediately, preferably in the same operation. Follow incorporation directions on label. The XT formulations include a UV-light protectant which can be surface applied or incorporated. Small grain may be seeded in rotation in the fall to prevent soil erosion, but may be stunted. Small grains used as rotation crops must be plowed under or otherwise destroyed. To avoid injury to crops not specified on the label, do not plant other rotational crops until 12 months after the last DEVRINOL application.

continued

Table 2. Herbicides recommended for use in tobacco fields.

Herbicide	Remarks and Limitations
Prowl 3.3EC 3 to 3.6 pt/A [medium soil texture] (*pendimethalin* 1.25 to 1.5 lb ai/A) [Use maximum 2.4 pt/A (1 lb ai/A) on course texture soils NC & VA] or **Prowl H2O** 3 pt/A [medium soil texture] (*pendimethalin* 1.4 lb ai/A) [Use maximum 2 pt/A (0.95 lb ai/A) on course texture soils NC & VA] Other products containing *pendimethalin* and labelled for use on tobacco include: **Acumen, Framework 3.3EC, Helena Pendimethalin, Pin-Dee 3.3EC, Satellite 3.3, Satellite Flex, Satellite HydroCap, Stealth** [consult product labels for application rates, etc.]	**Weeds Controlled:** Barnyardgrass, broadleaf signalgrass, crabgrass, fall panicum, foxtails, lambsquarters, pigweeds, purslane Apply to prepared soil surface up to 60 days prior to transplanting. Incorporate within 7 days after application within the top 1 to 2 inches of soil. Consult incorporation directions on label. Emerged weeds will not be controlled. Tobacco plants growing under stress conditions (cold/wet or hot/dry weather) may be injured where pendimethalin is used. Wheat or barley may be planted 120 days after application unless small grains will be planted in a no-tillage system.
Spartan 4F 8 to 12 fl.oz/A [medium soil texture] (*sulfentrazone* 0.25 to 0.375 lb ai/A) [Use 4.5 to 6 fl.oz/A (0.14 to 0.19 lb ai/A) for soils with course texture, <1.5% OM] Other products containing *sulfentrazone* and labelled for use on tobacco include: **Blanket, HM-1512 AG, Shutdown, Sulfin 4SC, Sulfentrazone 4L, Willowood Sulfentrazone 4SC, Zone 4F** [consult specific product labels for application rates, restrictions, etc.]	**Weeds Controlled:** Black nightshade, jimsonweed, lambsquarters, morningglories, pigweeds, prickly sida, purslane, smartweed Use the higher rate when weed pressure is heavy with morningglory or yellow nutsedge. Apply from 14 days before up to 12 hours prior to transplanting tobacco as a soil-surface treatment or preplant incorporated (less than 2 inches deep). Perform all cultural practices for land preparation, fertilizer/fungicide incorporation, etc. prior to application. If the soil must be worked after application but prior to transplanting, do not disturb the soil to a depth greater than 2 inches. Temporary stunting or yellowing of tobacco and localized leaf burns may be observed under some conditions with this treatment. Unacceptable crop injury can occur if applied post-transplant. SPARTAN and similar products may be impregnated on dry bulk fertilizers [consult label]. Proper mixing and uniform spreading of the impregnated fertilizer mixture on the soil surface is required for good weed control and to avoid crop injury. Rotational crops which may be planted include soybeans or sunflowers anytime; wheat, barley, or rye after 4 months; field corn after 10 months; alfalfa and oats after 12 months; and popcorn, sweet corn, and sorghum (for rates above 8 oz/A) after 18 months. See label for rotation guidelines with other crops.
Spartan Charge 10.2 to 15.2 fl.oz/A [medium soil textures] (*carfentrazone* 0.028 to 0.042 lb ai/A + *sulfentrazone* 0.25 to 0.38 lb ai/A) [Use 5.7 to 7.6 fl.oz/A (0.16 to 0.21 lb ai/A) for soils with course texture, <1.5% OM]	**Weeds Controlled:** Black nightshade, jimsonweed, lambsquarters, morningglories, pigweeds, prickly sida, purslane, smartweed Use the higher rate of SPARTAN CHARGE when weed pressure is heavy with morningglory or yellow nutsedge. Apply from 14 days before up to 12 hours prior to transplanting tobacco as a soil surface treatment or preplant incorporated (less than 2 inches deep). Perform all cultural practices for land preparation, fertilizer/fungicide incorporation, etc. prior to application of SPARTAN CHARGE. If the soil must be worked after application but prior to transplanting, do not disturb the soil to a depth greater than 2 inches. Temporary stunting or yellowing of tobacco and localized leaf burns may be observed under some conditions with this treatment. Unacceptable crop injury can occur if applied post-transplant. Rotational crops that may be planted include soybeans or sunflowers anytime; field corn, wheat, barley, or rye after 4 months; alfalfa, popcorn, sweet corn, and oats after 12 months; and sorghum (for rates above 10.2 fl.oz/A) after 18 months. See label for rotation guidelines with other crops.
After Transplanting—Postemergence Herbicides	
Poast 1.5E 1.5 pt/A (*sethoxydim* 0.28 lb ai/A) + Crop Oil Concentrate 2 pt/A or Methylated Seed Oil 1.5 pt/A [NOTE: *Consult labels for lower use rates if using other additives such as High Surfactant Oil Concentrates*]	**Weeds Controlled:** Barnyardgrass, broadleaf signalgrass, crabgrass, fall panicum, foxtails, johnsongrass, volunteer wheat POAST herbicide provides selective postemergence control of annual and perennial grasses. Apply any time from transplanting up to 7 weeks after transplanting tobacco, but avoid applications within 42 days of harvest. For adequate control, ensure good spray coverage using a spray volume from 5 to 20 GPA (gallons per acre). Use of spray additives such as High Surfactant Oil Concentrates may result in increased risk of crop injury. Do not cultivate within 5 days before or 7days after applying POAST. For rhizome Johnsongrass, more than one application may be needed. Make the first application of POAST (1.5 pt/A) when johnsongrass plants are 20 to 25 inches, followed by a second application of POAST (1 pt/A) when regrowth is 12 inches. A maximum of 4 pt/A of POAST can be applied per season to tobacco. As a spot treatment, prepare a 1% to 1.5% solution (1.3 oz/gal to 2 oz/gal) of POAST plus a 1% solution of Oil Concentrate (1.3 oz/gal) and apply to the grass foliage on a spray-to-wet basis. Do not apply more than 4 pt/A per season to tobacco, including POAST applied to seedbeds.

Fertilization

Bob Pearce, Edwin Ritchey, and David Reed

The primary goal of a good fertility management program for tobacco is to insure an adequate supply of mineral nutrients to produce high yields of good quality leaf. Fertility management begins with a good estimate of the capacity of the soil to supply nutrients to the crop. Soil types vary considerably across the regions where burley and dark tobacco are grown so the most reliable estimates of soil nutrient supply can be obtained from a soil test run at a lab operated by the land-grant university or department of agriculture in the state where you grow tobacco (Table 1). Soil tests at these labs often cost the grower very little, and the procedures and recommendations for each state have been thoroughly tested and reviewed over many years to provide growers with recommendations appropriate to local conditions. Tobacco fields should be soil tested at least 6 to 12 months before planting to allow sufficient time to plan for the correction of any deficiencies that may be identified. A soil test should be conducted at least every other year for all tobacco fields to be in compliance with the industry GAP program. Given the potential value of tobacco crops and the relatively low cost of soil testing, an annual soil test is advised. All tobacco growers should carefully review their contracts to ensure that fertility recommendations are also within the buyer-specified ranges for the type of tobacco they are growing.

Management of Soil pH and Liming

One of the most important pieces of information obtained from a soil test is the soil pH. Tobacco grows best when the soil pH is kept in the range of 5.8 to 6.5. To ensure the pH at mid-season does not fall below this range the target soil pH prior to planting is typically 6.2 to 6.6. When soil pH is outside of the optimum range, nutrient deficiencies or toxicities can occur. Throughout the regions where tobacco is grown, soil pH tends to go down over time due to applications of acidifying forms of nitrogen like urea or ammonium nitrate. Low soil pH can be easily corrected with applications of agricultural limestone. The neutralizing value of agricultural limestone (ag-lime) varies considerably among sources so be sure to consult your local county extension office or state department of agriculture for information on ag-lime quality in your area. Limestone should be applied far enough in advance of planting (6 to 12 months) to allow the ag-lime to react. It takes limestone around 2 years to fully neutralize soil acidity, but many of the negative aspects associated with low soil pH can be corrected within 6 to 12 months.

Pelletized limestone is often promoted to be a better and faster-acting alternative to ag-lime but it is considerably more expensive. Research at the University of Kentucky has shown that even though the relative neutralizing value (RNV) for pelletized limestone is typically higher than ag-lime, the reaction time is similar. Two factors influence the reaction time of pelletized lime: distribution patterns and the binding materials used to make the pellets. Pelletized lime comes into contact with less soil compared to ag-lime and is slower to neutralize soil acidity. Further, the lignosulfonate binding material used to manufacture the pellets must break down or solubilize before lime can become active to neutralize acidity. Even though the bulk of ag-lime applied may take a few months to a year to become fully active, there is generally several hundred pounds of fines (dust) per ton that react very quickly and can produce as much pH change in a short period of time as a few hundred pounds of pelleted lime added to the fertilizer. The practice of mixing low rates of pelletized lime with fertilizer is not a cost-effective way to manage soil pH and should not substitute for a good soil sampling and liming program.

Manganese (Mn) is a micronutrient needed by tobacco in very small amounts that can become toxic in some soils if the soil pH drops to 5.4 or below. Tobacco plants showing Mn toxicity will be stunted and have a mottled appearance with yellow leaf tissue between dark green veins. Symptoms are typically most noticeable between 4 to 6 weeks after transplanting. The stunting in severe cases of Mn toxicity can reduce leaf yields by as much as 400 lb per acre. By the time symptoms have been observed much of the damage has already occurred, however if caught early enough, a rescue treatment of 1000 lb per acre of bagged lime (finely ground limestone) may be applied and cultivated into the soil to minimize yield losses. This treatment is much less cost effective than following a regular program of soil testing and lime application to prevent Mn toxicity.

Nitrogen Management

Burley and dark tobacco require more nitrogen (N) than other tobacco types but not as much as has been historically applied in the traditional growing areas. Nitrogen recommendations vary from state to state but are in the range of 150 to 275 lb N per acre. Due to the transient nature of soil N in the regions where tobacco is grown there is no reliable soil test to predict N fertilizer needs. Recommended N fertilization rates depend primarily on the field cropping history and soil drainage class. The lower end of the rate scale is generally recommended for tobacco on well-drained soils following a sod or sod-legume crop. Higher amounts of N are recommended for tobacco following tobacco or row crops, and on soils with moderate or lower drainage classifications. Consult your local cooperative extension office for nitrogen rate recommendations tailored to the soils and local conditions of your area.

Ammonium nitrate (34-0-0) was the grower preferred source of N for burley and dark tobacco until it became difficult to find and more expensive due to security concerns. Calcium-ammonium nitrate (27-0-0) is available in some tobacco growing regions and contains the same proportions of ammonium-N and nitrate-N as ammonium nitrate, thus can be used in a similar manner. Other commonly available N sources (including urea 46-0-0) can be used satisfactorily for tobacco production, particularly on well-drained soils where a good liming program is followed, and soil pH is maintained in the range of 6.0 to 6.6. Nitrogen solutions (28 to 32 % N) are half urea and half ammonium nitrate and are good N sources for tobacco production in the areas where they are available. Handling liquid fertilizers requires specialized equipment but they are convenient and easy to apply. Once applied to the soil, the availability of nutrients to the plant are the same whether

Table 1. Additional resources for information on soil testing and recommended levels of fertilization for burley and dark tobacco

State	Publication	Title of publication	URL for online version of publication
KY	AGR - 1	Lime and Nutrient Recommendations	http://www2.ca.uky.edu/agc/pubs/agr/agr1/agr1.pdf
VA	Soil Test Note #9	Burley Tobacco	http://www.soiltest.vt.edu/PDF/soil-test-note-09.pdf
	Soil Test Note #7	Dark Fired Tobacco	http://www.soiltest.vt.edu/PDF/soil-test-note-07.pdf
NC		NC Agricultural Chemicals Manual	http://content.ces.ncsu.edu/fertilizer-use.pdf
PA	1065	Tobacco Recommendations	http://agsci.psu.edu/aasl/soil-testing/soil-fertility-testing/handbooks/agronomic/recommendations/misc/1065-tobacco
		Soil Testing	http://agsci.psu.edu/aasl/soil-testing/soil-fertility-testing
TN		Lime and Fertilizer Recommendations for the Various Crops of Tennessee	Lime: https://ag.tennessee.edu/spp/SPP%20Publications/chap1-limerecommends2008.pdf Fert: https://ag.tennessee.edu/spp/SPP%20Publications/chap2-agronomic_mar2009.pdf

the formulation of the fertilizer is dry or liquid. Fertilizers containing urea should be incorporated into the soil within 24 hours of application or treated with a urease inhibitor to reduce volatilization losses if the fertilizer is left on the soil surface. As little as 0.25 inches of rain occurring within two days of urea application will also sufficiently incorporate the urea-containing fertilizer to reduce volatilization losses.

If soil pH is moderately to strongly acidic (pH 5.8 or less) and no lime is applied, using a nonacid-forming source of N (sodium nitrate, calcium nitrate, or sodium-potassium nitrate) will lower the risk of manganese toxicity. In recent years, sodium nitrate and sodium potassium nitrate have become generally unavailable and calcium nitrate is expensive per unit of N. Timely ag-lime application is a more economical approach for pH management. If tobacco is grown on sandy soils or soils that tend to waterlog, using ammonium sources (urea, ammonium nitrate, ammoniated phosphates, ammonium sulfate, nitrogen solutions) will lower the risk of leaching and denitrification losses.

The entire nitrogen requirement can be applied pre-plant broadcast on medium-textured, well-drained soils. Applying broadcast nitrogen as near to transplanting as possible will significantly lessen the chances for losses of applied nitrogen during heavy spring rainfall events. Because losses of fertilizer nitrogen can occur on sandy soils (leaching) or soils with slow drainage (denitrification), it is helpful to split nitrogen applications on these types of soils, applying one-third of the nitrogen before transplanting and the remaining nitrogen two or three weeks after transplanting.

A project comparing combinations of pre-plant (PP) and side dress (SD) N rates was conducted in Kentucky, Tennessee, and Virginia with a total of 12 locations between 2004 and 2006. The results of this study showed that over all locations, cured leaf yields could be maximized with 80 lb PP + 100 lb SD, 160 lb PP + 50 lb SD or 240 lb PP with no SD (Table 2). At 9 out of the 12 locations, 160 lb N/A with no SD actually resulted in maximum yield, but in 3 of the trials, during wetter than average seasons, the crop did respond to an additional 50 lb of N side dressed. At no time did the crop respond to side dress applications when 240 lb of N was applied as a pre-plant application. A study conducted in Kentucky and Tennessee produced similar results, however, no benefit of added N was observed with N rates above 200 lb of N/acre (Table 3). These results are consistent with the N recommendations made for burley tobacco and clearly show no yield advantage to using higher than recommended rates of N. Excess nitrogen can result in lower quality due to green cured leaf, and contribute to higher levels of tobacco-specific nitrosamines (TSNAs). See TSNAs in Burley and Dark Tobacco, page 65.

Phosphorus and Potassium

Phosphorus (P) and potassium (K) are relatively stable in soils so fertilizer additions should be determined by soil testing. Soil test procedures and recommendations are optimized for the soil types in each state so you should use the recommendations provided by a land grant university or the department of agriculture in your state (Table 1).

Summaries of soil test results in several tobacco growing states have revealed relatively high levels of P and K in many fields with a history of tobacco production. Some fields may only require N for the current crop due to high levels of residual P and K. Growers are encouraged to take full advantage of soil nutrients to help reduce their fertilizer expenses and reduce potential environmental concerns associated with nutrient runoff.

Spring applications of potassium fertilizer for tobacco should ideally be made using a combination of muriate of potash (0-0-60) and sulfate of potash (0-0-50). One hundred pounds per acre of 0-0-60 supplying 60 pounds per acre of potash can be applied without negative impacts on leaf quality. Recent research has suggested that including muriate of potash can help reduce TSNAs in the cured leaf for both burley and dark tobacco. The balance of the potash requirement should be supplied by sulfate of potash because spring applications of chloride-containing fertilizers at rates greater than 50 lb of chloride per acre, can lead to excessive levels of chloride in cured leaf. Extremely high chloride levels in leaf lead to increased moisture retention, curing and storage problems, decreased combustibility, and ultimately, reduced quality and usability. Some tobacco company contracts specifically limit the amount of muriate of potash that can be applied during a growing season.

Table 2. Cured leaf yield of burley tobacco as impacted by pre-plant and side-dress nitrogen rates (average of 12 total trials over three years in Kentucky, Tennessee, and Virginia)

Side-dress Nitrogen (lb N/acre)	Pre-plant Nitrogen (lb N/acre)		
	80	160	240
	Cured leaf yield (lb/acre)		
0	2358	2520	2643
50	2527	2660	2659
100	2648*	2647	2652

* Yields shown in bold type are not significantly different from each other as determined by statistical analysis.

Recent shortages of sulfate of potash mean growers must consider other alternatives such as sulfate of potash-magnesia (K-mag, 0-0-22) or potassium nitrate (13-0-44) to meet their potash needs. Another option for growers to consider is fall applications of muriate of potash. Applying in the fall allows time for a portion of the chloride to leach below the root zone, limits the uptake of Cl and reduces potash fertilizer expenses compared to other sources. Leaf chloride levels are higher with fall applications than they are when sulfate of potash is used, but generally remain below the industry accepted standard of 1% chloride in cured leaf. Consult your local cooperative extension office to see if fall applications of muriate of potash are recommended in your area.

Secondary Nutrients

Secondary nutrients include Calcium (Ca), Magnesium (Mg), and Sulfur (S). Calcium levels are almost always adequate in soils maintained at the recommended pH for tobacco. Magnesium is usually adequate for tobacco growth; however, most soil test labs will report Mg levels. If low levels of Mg are noted on the soil test report, a grower may apply dolomitic lime, if lime is also required, or a product like sulfate of potash-magnesia. Documented sulfur deficiencies have been very rare on tobacco within the regions where burley and dark tobacco are grown. Only a few suspected cases of sulfur deficiency have been observed where fall applications of (0-0-60) were the sole source of potash over several years. Sulfur deficiencies can be easily corrected or prevented by using 0-0-50 (sulfate of potash), 21-0-0 ammonium sulfate, or elemental sulfur. Both ammonium sulfate and elemental sulfur will lower soil pH so the liming program may have to be adjusted when using these sources.

Micronutrients

Only two micronutrients are routinely recommended for burley or dark tobacco production. Molybdenum (Mo) is recommended for use on burley tobacco in Kentucky only when the pre-season soil pH is below 6.4 and lime has not been applied to correct the pH. Field trials have shown that setter water applications are equally as effective as broadcast applications for supplying molybdenum to the crop. Molybdenum can be purchased as a single nutrient product in dry or liquid formulations. Because Mo is a micronutrient, only very small amounts are recommended, higher amounts can become toxic to plants and animals.

For broadcast field applications, apply at the rate of 1 lb of sodium molybdate (6.4 oz of molybdenum) per acre. Dissolve this amount of dry sodium molybdate (or 2 gal of 2.5% Mo liquid product) in 20 to 40 gal of water and spray uniformly over each acre. Because sodium molybdate is compatible with many herbicides used on tobacco, it can be applied with herbicides normally applied as a spray in water. Combining the two chemicals can result in savings in application costs and reduces the chance of compacting the soil because only one trip over the field is necessary. It is recommended that not more than 2 lb of sodium molybdate (12.8 oz of molybdenum) per acre be used during a five-year period.

For transplant water applications, use 0.25 to 0.50 lb sodium molybdate (1.6 to 3.2 oz of molybdenum) per acre. Premixing dry material in a bucket of water before adding to the tank will aid in dissolving and mixing. Alternatively, you can use ½ to 1 gallon per acre of 2.5% Mo liquid formulation to supply 0.25 to 0.50 lb/A of sodium molybdate. If a liquid source of molybdenum is used add the liquid product to the tank before filling with water to aid with mixing.

Boron (B) deficiency has been reported on tobacco in Kentucky, Tennessee, and North Carolina. A common symptom noticed by burley and dark tobacco growers is leaf breakage. The midrib of the leaf is typically broken or cracked about 1 - 2 inches from the point of attachment to the stalk. Often there are a series of what appear to be small slits in the underside of the mid-rib near the area of the break. Another symptom observed on young tobacco is bud yellowing and distortion, eventually resulting in bud death in severe cases. Occasionally, a hollowed area has been observed in the pith of the stalk, just below the bud. Boron deficiency has been observed more often in dark tobacco than in burley and is often associated with soils that have a pH above 7.0. In fields with a high soil pH or a history of boron deficiency, a broadcast application of 0.25 to 0.5 lbs of boron per acre is recommended. The B application may be made as a pre-transplant broadcast spray or as a foliar spray after transplanting. As with all micronutrients, care must be taken to avoid over application that could lead to toxicity. Recent research with transplant water applications of B showed that as little as 0.5 lbs. B per acre delivered in 300 gallons of transplant water per acre was enough to cause B toxicity symptoms in young transplants.

No other micronutrient deficiencies have been reported for field grown tobacco in the areas where burley and dark tobacco are typically grown. Improper rates of certain micronutrients could result in toxicity to the plant, so they are not recommended on tobacco unless a deficiency has been identified.

Pre-blended Fertilizers

Pre-blended fertilizer products (sometimes called complete fertilizers) typically contain all three of the primary nutrients and often claim to have micronutrients as well. Pre-blended products offer convenience in that the majority of the crop's fertilizer needs can be met with a single application. The main problem with pre-blended products is that the primary nutrients are present in a fixed ratio making it difficult for the grower to meet the needs for one nutrient without over applying one or more of the others. Typical blends that have been used on tobacco include 5-10-15 and 6-12-18. At commonly used rates, these materials almost always result in an over application of P. After many years of repeated applications, some old tobacco patches have built up enough P to go several years with no P additions needed. Another precaution with blended products is to ensure that chloride levels are acceptable and use only products specifically intended for use on tobacco. Occasionally, some high-end fertilizers are promoted based on the added value of one or more secondary or micronutrients. However, if there is no true need for these nutrients the grower does not realize any of that added value in cured leaf yield.

Another form of pre-blended fertilizers includes foliar fertilizers. Foliar fertilizers are often promoted to be tank mixed with certain pesticides and applied as a broadcast foliar application. Most foliar products will contain macronutrients and some will

contain a mixture of other nutrients or "plant growth enhancement products" that are not justified or needed. These products can only be applied at low rates and haven't been shown to provide consistent yield benefits.

Animal Manures

Animal manures can be an excellent source of nutrients for crops, but some precautions need to be observed when using manure for tobacco production. Animal manures are also known to contain levels of chloride high enough to reduce the quality of cured tobacco. To avoid chloride problems, cattle and swine manure applications should be limited to no more than 10 tons per acre per year. Poultry manure should not be applied in the spring where tobacco will be grown. Fall applications of poultry litter should not exceed 4 tons per acre on ground where tobacco will be planted the following spring. Fall manure applications should be made only when a living cover crop will be present to take up and recycle some of the available N. Excessive rates of manure or manure used in conjunction with chloride-containing fertilizers may result in unacceptable chloride levels in the cured leaf. Where possible, it is probably best to utilize available poultry manure for other crops in the rotation and gain the benefit of their residual P and K in the tobacco crop without risking excessive chloride in the cured leaf. Soil and manure testing should be used to determine if supplemental applications of fertilizer will be needed.

Another recent concern about manure use on tobacco fields relates to potential crop injury from pasture herbicides containing the active ingredients picloram and aminopyralid. These herbicides can be passed into manure from animals consuming forage from treated fields, either as pasture or as hay. If cattle or horse manure is used on tobacco fields, it should not come from animals that have grazed pastures or eaten hay from fields treated with these herbicides.

Disease Management

Chuck Johnson, Emily Pfeufer, Zachariah Hansen, and Lindsey Thiessen

Management of Diseases in the Field

Tobacco diseases are responsible for lost revenue to growers each year as a result of reduced yield and leaf quality. Actual losses vary from year to year and farm to farm, depending upon the weather and diseases present. Tobacco is threatened by disease from seeding until harvest (and even during the curing process). As with transplant diseases, discussed earlier in this guide, the key to success in controlling diseases during field production is prevention. In almost every case, it is far easier to prevent disease than to stop it after an epidemic has gained momentum. And even if an outbreak of disease is brought under control through some type of rescue treatment, few of which are available for tobacco, yield losses can still occur and the quality of the crop can be reduced. Quality is especially important for dark tobacco due to the low tolerance of manufacturers for leaf spots and other disease-related damage.

Implementing a preventive disease management program means that control measures must be carried out or in place before disease appears. Field selection and choosing varieties and fungicides are decisions that should be made well in advance of seeding transplants to ensure availability of land, seed, and chemicals. Choosing the practices to be implemented requires knowledge of field history (previous crops, prevalent diseases, field characteristics) and an awareness of the diseases that affect tobacco. Following are recommended practices and tips for managing tobacco diseases in the field.

General Considerations

Take full advantage of resources to monitor and manage disease. During the growing season, check crops regularly for signs and symptoms of disease. If preventive programs are not already in place, best control of diseases will be achieved if action is taken early in an outbreak. Correct diagnosis of diseases is the first step in bringing these problems under control. If the cause of a problem is in doubt, local extension agents should be consulted. Your agent can help get a correct diagnosis through a plant diagnostic laboratory. Tobacco-related extension publications are available at your county extension office.

Avoid planting tobacco in areas with histories of severe disease problems. One of the best ways to keep a particular disease from affecting a crop is to not plant tobacco in areas where problems have occurred in the past. This practice is particularly effective for management of black shank and Fusarium wilt. If plant viruses have been a significant problem in the past, avoid areas with large unmanaged populations of weeds. Crops in areas with partial shade and/or extended periods of high humidity are more likely to have fungal leaf spot problems.

Plant at optimum time for your location and situation. Each area where tobacco is grown has an optimum window for planting depending on the local climate. Planting early in that window may result in more significant problems from black root rot and black shank when varieties susceptible to these diseases are planted. In determining optimum planting date, the length of the growing season must be considered along with the history of past disease problems for the location. Overall, any environmental aspect (soil moisture, compaction, very hot temperatures, etc.) that stresses young transplants has potential to make them more susceptible to disease.

Rotate with non-related crops. Crop rotation is a highly effective tool for preventing and managing diseases, particularly those caused by soilborne pathogens and nematodes or those that result from carry-over in crop debris. Do not follow tobacco with tobacco, especially if black shank, black root rot, or Fusarium wilt are observed in a field. Frogeye leaf spot, caused by *Cercospora nicotianae*, has been reported on soybean, which makes soybean a poor rotation partner where frogeye is a major concern. Rotating with sweet potato is discouraged due to the potential for Fusarium wilt carryover. Regular rotation away from tobacco and related crops deprives pathogens of their preferred nutrient source, slowing their buildup or causing their numbers to decline over time. The effectiveness of rotation improves as the length of time away from tobacco is increased.

Three to five years out of tobacco after a single season in tobacco should provide good control of soil-associated diseases for most growers. Although less than ideal, short rotational intervals (under three years, but not sequential tobacco) can reduce disease pressure in fields after a serious disease outbreak, but longer intervals are more effective. Unfortunately, crop rotation is not effective against all diseases. Diseases caused by pathogens that don't overwinter in soil, on plant debris, or with weeds, like blue mold, are not affected by crop rotation.

Select and prepare sites properly. Do not set plants into saturated soils or in areas that tend to accumulate water. Choose a site that is well drained to avoid soil saturation which can result in poor establishment. Install ditches or drain tiles if needed to promote good soil drainage. Select sites that are not excessively shaded and have good air movement in order to suppress diseases like target spot, frogeye leaf spot, and blue mold. Incidence of alfalfa mosaic virus is often linked to adjacent alfalfa fields. Do not plant tobacco adjacent to areas where vegetables are produced, as many vegetable crops (especially tomatoes and peppers) can harbor viruses that can move into tobacco by insect vectors. By the same token, don't plant tomatoes or peppers in tobacco fields. Manage weeds, both in and directly adjacent to fields, to reduce their influence as sources of viruses and some fungal pathogens.

Exclude plant pathogens from the field. Plant pathogens often travel from infested to clean fields on vehicle tires, farm equipment, farm animals, and shoes. Cleaning and sanitizing equipment and shoes with 10% bleach between fields will reduce disease spread from one field to another, but this is time-consuming and could be impractical for many growers. Another solution that should reduce soil-associated disease spread would be for a grower to work their least diseased fields first and end the workday with the most diseased areas. A thorough equipment cleaning at the end of the day is then recommended. This is particularly important when you know that only some fields contain diseases like black shank and Fusarium wilt, and when commercial or shared equipment moves into your field from different areas. To avoid introducing pathogens, don't discard stalks from fields with black shank and other diseases in clean fields or near sources of surface water (streams, ponds, etc.). Use transplants produced as locally as possible. The further south plants are produced, the more likely they may be to have been exposed to blue mold, and their importation could start an outbreak early in the season.

Plow cover crops early. This practice will ensure that plant matter decomposes thoroughly before setting time. Sore shin and black root rot can be problems in fields with high levels of partially decomposed organic matter. Heavily manured fields may have higher severity of black root rot. Turn tobacco roots and stubble under soon after harvest to promote decomposition and a more rapid decline of soilborne pathogens.

Manage soil fertility and pH. Keep soil pH within recommended ranges during the growing season. Do not over fertilize, as it favors development of angular leaf spot, blue mold, and black root rot. However, low nitrogen levels can contribute to severe outbreaks of target spot and brown spot, so be sure to use recommended, moderate amounts of nitrogen fertilizers for optimal crop production.

Go to the field with healthy transplants. Don't set plants with *Pythium* root rot or other diseases. Diseased plants tend to take longer to establish and are more likely to be affected by black shank and sore shin. Do not set plants that have blue mold and destroy them immediately. Such plants will almost always die. If they do survive, they will not thrive and will serve as a source of spores for outbreaks in surrounding fields. Avoid tobacco use (smoking or chewing) during setting to prevent the transmission of tobacco mosaic virus.

Plant disease-resistant varieties. Select varieties with resistance to the diseases that you anticipate being a problem. Burley varieties are available with good resistance to diseases such as black shank, blue mold, Fusarium wilt, virus complex, tobacco mosaic, and black root rot (see articles on selection of burley and dark tobacco varieties on pages 3 and 7). Look at the entire resistance "package" when choosing a variety, as levels of resistance to individual diseases can vary and may not be appropriate for some fields. For example, NC 2002 has good resistance to blue mold but no resistance to black shank and would be a poor choice to plant in areas where black shank has been a problem. Varieties such as KT 206 and KT 209 are great choices for black shank fields but are completely susceptible to Fusarium wilt. While KT 210 and KT 215 possess increased resistance to Fusarium wilt, in addition to moderate to high resistance to black shank, neither is resistant to aphid-transmitted viruses.

Use fungicides correctly. Timely and accurate application of fungicides is essential for best performance. The following are some general guidelines for successful use of fungicides to manage tobacco diseases:

- **Do not use products that are not approved for tobacco.** By the same token, don't use tobacco-approved products in ways that are not outlined on the products' labels. Pay attention to safety precautions, preharvest intervals, and observe guidelines for resistance management.
- **Apply fungicides preventively, or at the latest when first symptoms of disease appear.** Most products labeled for tobacco are protectants and must be in place before the arrival of the pathogen to suppress infection. Applications made after a disease has become established will be less effective, or worse, may not be successful at all. Maintain recommended application intervals while disease threatens, or the weather favors disease. When high levels of disease are present, applying fungicides with a specific mode of action (such as Quadris or Forum) could lead to resistance development in certain plant pathogens, which is another reason to apply fungicides preventatively.
- **Use an application volume that gives the best coverage of plants.** For most fungicides, this amount will change as the crop grows. For foliar fungicides in general, use 20 gal/A near transplanting, increasing to 40 gal/A when plants are knee-high, 60 gal/A when plants are waist-high, 80 gal/A when plants are chest-high, and as much as 100 gal/A for applications made at topping or afterward. Spray pressure should be between 40 and 100 psi. As application pressure increases, so does foliar fungicide coverage as well as the risk of drift. As the crop grows, configure sprayers, if possible, with one nozzle centered over the row and multiple nozzles

on drop extensions to allow for good coverage in the middle and lower canopies. Fungicide sprays for soil-associated diseases (e.g. black shank) should be directed toward the base of plants and cultivated in for best results.

- **Calibrate sprayers for accurate delivery** to ensure the crop receives neither too little fungicide (poor disease control) nor too much (extra cost and potential injury). Regularly clean nozzles and change them as they become worn. Nozzle replacement is an extra expense that will pay for itself in the long run. When purchasing nozzles, consider ceramic or stainless-steel tips. These types of nozzles are more expensive than their brass counterparts but last longer and are accurate.
- **Harvest in a timely manner and correctly manage barns.** Over-mature tobacco is more prone to leaf-spotting diseases, such as brown spot. Manage humidity levels in barns to avoid houseburn and barn rots.

Common Diseases and Their Management

Angular leaf spot and wildfire. In recent years, angular leaf spot has become an influential disease in dark tobacco, but overall these bacterial diseases are minor issues for burley producers. Crop rotation and good sanitation practices can be useful in suppression of angular leaf spot and wildfire. The majority of burley varieties are resistant to wildfire, but not angular leaf spot. Many dark varieties are very susceptible to angular leaf spot. Dark tobacco cultivars DF 911, TN D950, KT D6LC, KT D14LC, and PD 7305LC all possess high resistance to wildfire. Dark tobacco cultivars PD 7309LC, PD 7318LC, DT 538LC, and Little Crittenden are less susceptible to angular leaf spot. Cultivars KT D17LC and TN D950 are highly susceptible to angular leaf spot. See Selecting Dark Tobacco Varieties, page 7, for more information. Use of chemicals to manage these diseases is marginally effective; however, agricultural streptomycin (Table 3) can be applied preventively or after symptoms first appear at 200 ppm (16 oz/100 gal). Continue applications while conditions favor disease development (typically warm, wet conditions or frequent thunderstorms with high winds).

Black shank. Black shank is by far the most important disease of burley and dark tobacco. Use good sanitation practices to prevent introduction and spread of the pathogen. Once introduced into a field, the black shank pathogen (*Phytophthora nicotianae*) can never be completely eradicated. Crop rotation is a key consideration in both prevention and management of black shank. Simply put, there's no better tool to manage black shank than crop rotation. The black shank pathogen survives and reproduces mainly on tobacco, so continuous planting of tobacco will lead to increased populations over time. Rotation slows the buildup of *P. nicotianae* and other pathogens in the field by depriving them of their preferred host. Rotation away from tobacco for even a year will reduce disease; however, rotations of three to five years have the greatest impact on black shank. Several crops serve as good rotation partners with tobacco, including grass hay and pasture, corn, and sorghum. Legumes (alfalfa, clover, etc.) and vegetables will reduce black shank levels, but may promote the buildup of other soilborne pathogens responsible for diseases like black root rot. Plant pathologists do not recommend rotating soybean with tobacco because, although soybean can be beneficial for growers from an agronomic and economic standpoint, it increases tobacco disease problems.

Field location is an important consideration for managing black shank. Fields with relatively high soil pH levels have been associated with increased disease. Avoid planting in fields that are down slope from areas that have had black shank in the past or those that could receive water runoff from infested fields. Steps should be taken to minimize soil saturation, since these conditions favor infection by *P. nicotianae.* Eliminate areas in fields where water stands, or install tiles to improve drainage. Keep in mind that, if irrigating, water from ponds, rivers, or creeks could be contaminated with the black shank pathogen, and using water from these sources could result in severe problems with black shank in the future.

Using a resistant variety is an excellent tool for managing black shank, and choosing the right variety is one of the most important management decisions a grower will make. Resistant varieties combined with good crop rotation and a sound fungicide program offer the best possible control of this disease. Black shank can be caused by several races of *P. nicotianae,* but is now almost always caused by race 1 ***in burley tobacco.*** Either race 1 or race 0 may be problematic in dark tobacco. Burley tobacco cultivars KY 14 x L8LC, KT 206LC, KT 209LC, KT 210LC, KT 212LC, KT 215 LC, NC7 LC, HB 3307PLC, and HB 4478PLC and dark tobacco cultivars KT D14LC, PD 7302, PD 7305, PD 7309, PD 7318, and PD 7319LC all possess a source of black shank resistance (the Ph_1 or Ph_P genes) that provides a resistance rating of "10" for race 0, but have lower (or no) resistance to race 1. Common burley varieties and their resistance ratings to black shank can be found in "Selecting Burley Tobacco Varieties." Refer to "Choosing Dark Tobacco Varieties" for a list of commonly grown dark varieties and their levels of black shank resistance.

Field history, in terms of crops and varieties grown and previous severity of black shank, should be considered when deciding on a variety to grow. Planting a variety with little or no resistance (0-3 on the rating scale) may be, but is not always, "safe" in fields with no history of disease. Fields with a history of black shank and/or a short crop rotation interval should be planted with cultivars possessing at least moderate to high resistance to race 1 (4-8 on the rating scale). These cultivars also possess resistance to race 0 that is at least as high, or higher, than that to race 1. The safest bet for growers is to also supplement use of black shank resistance with use of a black shank fungicide in transplant water.

For chemical control of black shank, use products containing oxathiapiprolin (Orondis Gold 200), fluopicolide (Presidio), mefenoxam (Ridomil Gold, Ultra Flourish), or metalaxyl (MetaStar) (Table 2), in conjunction with resistant varieties (4 or better on the rating scale) and crop rotation. As with all fungicides, ensure the product intended to be used is labeled for use in your state. In most cases, fungicides will not provide acceptable control of black shank if applied to varieties with little or no resistance, nor will a single fungicide application provide acceptable black shank control. Adequate soil moisture is needed for best performance of some products because root uptake may be required for them to be effective. If black shank fungicides are used pre-plant, they should be applied no more than 7 days before planting, and at the rates found in Table 2.

Table 1. Nematicides for nematode control on tobacco.

Material[a]	Rate/Ac[b]	Method of Application	Waiting Period	Control Rating[b]
Chloropicrin 100 Chlor-O-Pic 100 (chloropicrin)	3 gal	Fumigant—row[c]	21 days	Fair-Good
Pic + (chloropicrin 86%)	4 gal	Fumigant—row	21 days	Fair-Good
Telone II (1,3-d)	6-9 gal	Fumigant—row	21 days	Good-Excellent
Velum Prime (Fluopyram 41.5%)	6.5-6.84 fl oz/ac	Transplant water	0 days	Fair
Nimitz (Fluensulfone 40%)	3-7 pints/ac	Non-fumigant – preplant incorporated	7 days	Fair

[a] Nematicides can damage plants under certain conditions. Greenhouse-produced plants may be more sensitive to this type of injury.
[b] Control may be variable.
[c] Apply 6 to 8 inches deep. Fumigants work best and cause the least injury when applied at soil temperatures above 50°F and when the soil is moist but not wet. Fumigants should be injected into a pre-formed high, wide planting bed. Rates are based on injection volumes; broadcast fumigant rates will be different than those listed above.
[d] Non-fumigant nematicides vary in efficacy.

Use a volume of water or fertilizer sufficient for good soil coverage and incorporate into the top 2 to 4 inches of soil by disking or irrigation. The Ridomil Gold and Ultra Flourish labels also allow the initial soil application to be made as soon as possible after transplanting and has the advantage of concentrating the chemical in a band. However, its success depends on adequate soil moisture; irrigation or rainfall may be needed for activation when soils are dry, but excessive water can lead to product loss. Transplant water use of Ridomil Gold is labeled at 4 to 8 fluid ounces per acre (depending on soil type). Transplant water application of Orondis Gold 200 should include 4.8 fluid ounces of product plus Ridomil Gold for early season *Pythium* control and to avoid fungicide resistance development. Orondis Gold Premix includes the same active ingredients as Orondis Gold 200 (oxathiapiprolin) and Ridomil Gold(mefenoxam) and is now registered for transplant water use (only) at 24 to 27.8 fluid ounces per acre. Application of Orondis Gold at these rates supplies similar amounts of black shank fungicides as 4 to 5 fluid ounces of Orondis Gold 200 plus 5 to 6 fluid ounces of Ridomil Gold. All transplant water uses require at least 200 gallons of transplant water per acre to avoid damage to plants. Presidio should not be applied in the transplant water. For full season control of black shank, supplemental applications of Ridomil Gold (1 pt), Presidio (4 oz/A), Ultra Flourish (2 pt), or MetaStar (2 qt) can be made at layby, OR at first cultivation and then again at layby. The MetaStar label prohibits post-transplant applications when more than 2 qt of MetaStar was used prior to transplanting, or if none was used. Applications of these black shank fungicides should total no more than 3 pt/acre for Ridomil Gold, 27.8 fluid ounces of Orondis Gold Premix, 38.6 fluid ounces of Orondis Gold 200, 12 fluid ounces of Presidio, 6 pt/acre for Ultra Flourish, or 6 qt/acre for MetaStar. These field sprays should be directed toward the soil and incorporated immediately by cultivation. Do not apply these products over the top later in the season, since any chemical intercepted by tobacco leaves will not be taken up by the roots, limiting the effectiveness of the treatment. Development of fungicide resistance is a real concern for Presidio, Orondis Gold 200, and Orondis Gold Premix. For this reason, rotate the products applied when multiple fungicide applications are made in a single growing season. For example, if Orondis Gold plus Ridomil Gold is applied in transplant water, Presidio should be applied at first cultivation or layby to reduce the risk of fungicide resistance development. Black shank is listed on the labels of some soil fumigants, but these are not intended to replace early fungicide applications for black shank. Overall, fumigation is meant to broaden control of other soilborne pathogens (when present), and fumigation is not cost effective if black shank is the only target.

Black root rot. Once one of the most destructive diseases of burley tobacco, black root rot is now only a sporadic problem. Resistance to black root rot in many burley and dark tobacco varieties has reduced the importance of this disease in recent years. Table 3 in the "Selecting Burley Tobacco Varieties" and Table 1 in the "Selecting Dark Tobacco Varieties" present the specific reactions of current tobacco varieties to black root rot. Despite the decreased importance of black root rot, *Thielaviopsis basicola* is present in soils in many parts of the region and could pose problems to producers who do not rotate routinely or plant varieties with little or no resistance to this disease.

Use good sanitary practices to avoid introduction of *T. basicola*. Once introduced into a field, the black root rot pathogen can persist in soil for several years. This disease can be managed successfully through an integrated approach that includes crop rotation and resistant varieties. Do not follow leguminous crops (snap beans, soybeans, clover, alfalfa) with tobacco. By-products from decomposition of rye and barley residues are also believed to increase the susceptibility of tobacco to the black root rot fungus, making these crops a risky choice for cover crops in areas with a history of the disease. Avoid planting in cool soils and excessive use of lime (keep soil pH between 6.0 and 6.4 for burley). Black root rot can be aggravated by large amounts of undecomposed organic matter. Incorporate manure and cover crops early in the spring to permit as much decomposition as possible before transplanting. Soil fumigants are labeled for suppression of black root rot, but their use may not be economically practical in most situations.

Blue mold. Blue mold has caused serious losses in years when cool and rainy conditions have prevailed, particularly early in the season. The blue mold pathogen, *Peronospora tabacina*, does not normally overwinter in traditional burley growing areas and requires a living host to survive. When tobacco is killed by freezes in late fall, surviving *P. tabacina* is eliminated as well. Epidemics of blue mold normally begin from introductions of *P. tabacina* from areas where the pathogen may overwinter*; typically those that are frost-free.* In rare cases, the blue mold

pathogen may overwinter in burley regions on tobacco in protected environments (old float beds or greenhouses), which is a key reason to ensure that unused tobacco is destroyed after transplanting in the spring. Management of blue mold should begin with the use of disease-free transplants; avoid transplants produced south of Tennessee. If planting into areas that are prone to blue mold, select a variety with partial resistance (see articles on variety selection on pages 3 and 7).

Chemicals registered for control of blue mold are listed in Table 3. Fungicides are good, but not perfect, tools for managing blue mold if used properly. Begin fungicide applications for blue mold control when the disease is forecast to threaten your area or has been found nearby. Contact your county Extension agent for disease advisories. Once blue mold has been reported or threatens an area, fungicides should be applied at regular intervals as long as conditions favor development of the disease.

Quadris is labeled for control of blue mold, frogeye, and target spot. While not as effective against blue mold as Forum + mancozeb, and perhaps Revus, Orondis Ultra, and Presidio, our results indicate that Quadris provides consistent and effective control of blue mold if applied on a preventative basis. Keep in mind that Quadris has limited systemic activity. Do not make Quadris the first fungicide application when blue mold is found in a field. Applications of this product should begin before symptoms are observed in the field, when blue mold threatens. If blue mold is present in a field, apply Forum tank-mixed with mancozeb, or Revus, Orondis Ultra, or Presidio, and follow with Quadris seven to ten days later. Do not make back-to-back applications of Quadris; rotate to another fungicide or program (mancozeb or Forum + mancozeb) after each application of Quadris. Good coverage is critical in getting good foliar disease control, and using drop nozzles is the only way to obtain good coverage of mid-stalk and lower leaves. Boom sprays cannot provide good coverage beyond the upper leaves. Pay particular attention to product preharvest intervals when managing blue mold; as of 2020, the PHIs for various products are 30 days for mancozeb, 21 days for Quadris and other azoxystrobin products, and 0 days for Forum. In certain cases, injury in the form of flecking has been associated with the use of Quadris on tobacco and has been severe. However, significant loss of yield or quality is extremely rare. Damage from Quadris is more likely when applied as a tank-mix. Severe damage can occur when it is mixed with sucker control materials or EC pesticides.

Other options for blue mold control include Forum, Revus, Orondis Ultra, Presidio, Manzate ProStick or Penncozeb (mancozeb products), Aliette WDG, and Actigard. Forum is a liquid formulation of dimethomorph. Resistance management is an important consideration with Forum, Orondis Ultra, Presidio, and Revus. According to the Forum and Presidio labels, these products must be tank-mixed with another blue mold fungicide for management of resistance; mancozeb works well in this role. Revus and Orondis Ultra are labeled only for control of blue mold; Orondis Ultra is a mixture of Orondis with Revus. Revus and Forum have the same mode of action and should never be tank-mixed together or sprayed sequentially with each other. Presidio must not be applied for blue mold control if it has already been applied as a black shank treatment; Orondis Ultra must not be used for blue mold control if Orondis Gold Premix or Orondis Gold 200 have already been applied for black shank control. Growers must not make more than two consecutive applications of any of these newer blue mold fungicides, but alternate among fungicides with different modes of action when multiple blue mold sprays are necessary.

Actigard remains one of our best options for blue mold control. It is a systemic product that functions by inducing plant defenses and, thus, is not a true fungicide. Coverage is not as critical with Actigard as with other fungicides, so this product may be applied with standard broadcast-type equipment and will still give good control of blue mold. Activation of host defenses takes several days for full protection, so Actigard should be applied four to five days before tobacco is exposed to the blue mold pathogen. If infection threatens before the four-to-five-day activation period, Actigard should be tank-mixed with another fungicide to protect plants during this critical time. A second application made 10 days after the first has been shown to extend good protection against blue mold. See Actigard remarks in Table 3 for additional information. If blue mold threatens tobacco that is less than the recommended height, use another fungicide until Actigard can be applied. Do not apply Actigard to stressed plants.

Aliette is also labeled only for blue mold. The first application of Aliette should be made immediately after transplanting, and subsequent sprays can be made on a seven-to-ten-day schedule. Aliette should not be tank-mixed with copper compounds, surfactants, or foliar fertilizers, and the pH of the spray solution should not be less than 6.0. Results from Kentucky research suggest that this product does not suppress blue mold as effectively as other labeled options.

Ridomil Gold, Ultra Flourish, and MetaStar are labeled for control of blue mold but should not be relied upon to manage this disease.

Brown spot and ragged leaf spot. These diseases tend to be problematic on burley and dark tobacco later in the season, but only sometimes cause economic losses. Proper rotation, deep-turning of crop residues, wider plant spacing, and timely harvesting can help prevent problems with brown spot and ragged leaf spot. In burley, some varieties are reported to have partial resistance to brown spot (KY 14×L8, NC 7). A fungicide program that contains mancozeb and Quadris should provide some suppression of these diseases.

Frogeye leaf spot. Frogeye, caused by *Cercospora nicotianae*, is a common leaf spot in some burley and dark tobacco production areas. Recent work in multiple states has indicated that reduced sensitivity to azoxystrobin fungicides (Quadris and generics) has been established on many farms, but thresholds for actual control failures have not been established yet. Resistance to azoxystrobin can occur at two different levels, moderate and high. Research has demonstrated that moderately resistant frogeye fungi tend to be more common among and within farms. Multiple replicated field trials have demonstrated adequate control of frogeye leaf spot is attainable by implementing an alternated three-spray program of azoxystrobin (Quadris) followed by mancozeb or another protectant, followed by azoxystrobin (Quadris). This should be initiated 3 to 4 weeks after transplant, and completed prior to topping. Leaf loss or weight reduction due to frogeye can be severe in rainy

Table 2. Guide to fungicides available for control of black shank. Do not use for black shank control in Pennsylvania.

Fungicide (FRAC Code)	Season Rate/A	Pre-plant or at-planting applications			Post-plant applications	
		Method	Rate/A*	Remarks	Rate/A*	Remarks
Orondis Gold Premix (49)	27.8 fl oz	Transplant water only	24-27.8 fl oz	Apply in no less than 200 gallons of transplant water per acre.	N/A	N/A
Orondis Gold 200 (49)	36.4 fl oz	Transplant water OR Post-plant	4.8 fl oz	Apply mixed with 6-8 fl oz Ridomil, at planting in-furrow or in transplant water. Rates up to 19.2 fl oz/A are labeled, such as in heavier soils. Apply in no less than 200 gallons of transplant water per acre.	4.8 fl oz	Apply mixed with 6-8 fl oz Ridomil, as a banded post-plant application to the soil at 1st cultivation or layby. Rates up to 19.2 fl oz/A are labeled, such as in heavier soils. Do not use if Orondis Gold has already been applied.
Presidio (43)	8 fl oz	NA	NA	NA	4 fl oz	Make banded application directed at soil beneath leaves at 1st cultivation or layby.
Ridomil Gold SL (4)	3 pt	Transplant water + Post-plant	¼-½ pt	Apply in no less than 200 gallons of transplant water per acre.	1 pt	Make subsequent application(s) at 1st cultivation and/or layby.
		Pre-plant + Post-plant	1 pt	Apply to soil within 1 week before planting and incorporate into the top 2-4 inches of soil.	1 pt	Make 1st application as near as possible to transplanting if no pre-plant application was made or if black shank is expected early in the season. Otherwise, make application(s) at layby or at 1st cultivation and layby.
		Pre-plant only	1-2 pt	Apply to soil within 1 week before planting and incorporate into the top 2-4 inches of soil.	----	----
Ultra Flourish (4)	6 pt	Pre-plant + post-plant	2 pt	Apply to soil within 1 week before planting and incorporate into the top 2-4 inches of soil.	2 pt	Make 1st application as near as possible to transplanting if no pre-plant application was made or if black shank is expected early in the season. Otherwise, make application(s) at layby or at 1st cultivation and layby.
		Pre-plant only	2-4 pt	Apply to soil within 1 week before planting and incorporate into the top 2-4 inches of soil.	--	--
MetaStar 2E (4)	12 pt	Pre-plant + post-plant	4 pt	Apply to soil just prior to planting and incorporate into the top 2-4 inches of soil.	4 pt	Do not make a post-plant application of MetaStar if more than 4 pt was used pre-plant or if none was used pre-plant. Post-plant application(s) may be made at layby or at 1st cultivation and layby.
		Pre-plant only	8-12 pt	Apply to soil just prior to planting and incorporate into the top 2-4 inches of soil.	--	--

* Rate range of product. In general, use the highest labeled rates when disease pressure is high. Refer to product label for application information, restrictions, and warnings.

seasons, and quality losses can occur from green spots that appear during curing as the result of late infections. Even light cases of frogeye can cause considerable reduction in value of dark tobacco, where leaf quality is of paramount importance.

Target spot. Caused by *Thanatephorus cucumeris*, target spot has become increasingly prevalent, and yield losses of 50% or more have been observed in some areas. High humidity and moderate temperatures favor this disease, making target spot a serious problem under prolonged wet weather and in fields that are shaded or have poor air flow through the plant canopy. Target spot tends to worsen as the crop grows. When the row middles close, significant shading occurs in the lower canopy and humidity increases, favoring development of target spot.

Cultural practices recommended for management of target spot and frogeye include crop rotation, deep-turning of crop residues, wider plant spacing, mowing of weedy field borders, and timely harvesting. Additionally, do not under- or over-fertilize tobacco. Low nitrogen fertility can predispose tobacco to infection by the target spot pathogen, as can the presence of lush growth brought on by excessive nitrogen.

Azoxystrobin (active ingredient in Quadris and generic products) is the only systemic fungicide option for management of frogeye and target spot (Table 3). However, Quadris cannot be applied back-to-back; therefore, unrelated fungicides must be applied between Quadris applications. Mancozeb and copper are only slightly effective against frogeye and target spot,

but are the only choices for this purpose at this time. Mancozeb residues are an industry concern, so only use Manzate or Penncozeb within the first 7 weeks after transplanting in order to minimize the risk of high residue levels. Fungicidal control of fungal leaf spots is dependent on multiple factors, including field history, rainfall, and the type of tobacco grown. Generally, a rate of 8 fl oz Quadris/A provides adequate control of fungal spots while minimizing the risk of potentially severe flecking. Foliar fungicides may need to be applied on a 10- to 14-day schedule during rainy periods, alternating mancozeb and Quadris applications. This program should be started early for most effective control of leaf spots. For target spot control, Kentucky research has shown that the spray program should begin when plants are 24 to 36 inches tall. Although leaf spots cause most of their damage after topping, early fungicide applications will minimize late-season damage by suppressing the buildup of pathogen populations.

Fusarium wilt. Caused by *Fusarium oxysporum* f.sp. *nicotianae*, this soilborne disease can severely impact tobacco, particularly in fields with a history of disease or continuous tobacco. Warm conditions favor development of Fusarium wilt, and severity of disease can be aggravated by drought. Good management practices can help stave off losses to Fusarium wilt. Sanitation can help prevent introduction of the pathogen into "clean" fields. Planting tobacco after sweetpotato or cotton can increase chances of damage from Fusarium wilt. Avoiding fields with a history of severe Fusarium wilt, if possible, may be the best plan. Unfortunately, many of the varieties that are most effective against black shank (such as KT 204, KT 206, and KT 209) are extremely susceptible to Fusarium wilt. Burley varieties KT 210, KT 215, KY 14×L8, and NC 7 have moderate resistance to Fusarium wilt, but KT 210, KT 215 and KY 14×L8 are susceptible to viruses, while NC 7 has lower resistance to race 1 black shank and KY 14×L8 is very susceptible to race 1 black shank. When dealing with both black shank and Fusarium wilt in the same field, KT 210 and KT 215 (new varieties with good resistance to black shank plus moderate resistance to Fusarium wilt) should be planted.

Bacterial soft rots, including black leg, hollow stalk, and bacterial leaf drop. These diseases are all caused by the same bacterium, *Pectobacterium carotovorum* subsp. *carotovorum*. Hollow stalk and bacterial leaf drop typically occur after topping. Warm and humid conditions, and in particular frequent rains, favor development of hollow stalk. To reduce bacterial disease incidence, ensure that crops are not over fertilized. Minimize mechanical and chemical wounding during topping and sucker control operations, and don't top during rainy or overcast conditions or if plants are wet. Growers should top tobacco in the bud stage and consider cutting tops at an angle to reduce water retention, reducing the potential for infection. Chemical control of hollow stalk is not possible.

Virus diseases. Virus diseases can be damaging, but their severity depends upon the year and the varieties being grown. Chemical control of virus diseases is not possible. Planting a resistant variety is the most effective practice for prevention of most virus diseases of tobacco, and many burley cultivars possess this resistance. TN 86LC, N777LC, HB3307PLC, and KT 215 LC are not resistant to tobacco mosaic virus. See Selecting Burley Tobacco Varieties, page 3, for the resistance or susceptibility of specific varieties to aphid-transmitted viruses. Control of insect vectors gives variable and unpredictable levels of control of aphid-transmitted viruses or tomato spotted wilt virus (thrips). Weed control in and around fields can be helpful, as weeds serve as reservoirs of some virus diseases; don't plant tobacco near vegetables or alfalfa for the same reason. Tobacco surrounded by, or planted adjacent to corn, soybeans, or other small grains will have fewer problems with aphid-transmitted diseases, as the insects "lose" the virus as they feed on these crops before moving onto tobacco.

Nematodes. Plant-parasitic nematodes are rarely a serious problem in burley tobacco fields and tend to gradually become a yield limiting factor over several cropping cycles. However, nematodes have occasionally been found to damage burley and dark tobacco, often in fields with sandier soils, and particularly in bottom land along streams, or sometimes when burley follows legume forages. Above-ground symptoms are typically irregular stunting and slow growth, associated with poor root growth or root galling. Prior to utilizing Table 1, diagnosis by a plant diagnostic lab is recommended, since nematode problems tend to be rare.

Chemicals for Disease Control

Several fumigants are registered for use on tobacco for preplant suppression of soilborne pathogens and nematodes. (Table 1). Chloropicrin used as a preplant soil treatment will also reduce early populations of *P. nicotianae, Rhizoctonia, Fusarium, Pythium,* and *Thielaviopsis,* but the length of control to be expected is uncertain. Soil fumigants are hazardous, expensive, must be applied with specialized equipment, and generally require significant extra safety equipment, an additional pesticide applicators' certification, signage, and documentation. Non-fumigant nematicides are a new option for dark and burley tobacco producers, and are also listed in Table 1.

Tables 2 and 3 list labeled chemicals for use in the production of burley and dark tobacco as of December 2020. As always, read all product labels carefully and follow all directions provided by the manufacturers. Each product has specific use directions that must be followed to minimize the risk of damage to the crop and to maximize the effectiveness of the product. Information provided in the tables is meant to serve as a general set of guidelines to aid in product selection but is not intended to replace product labels.

Table 3. Guide to chemicals available for control of tobacco diseases in the field, 2015—foliar applications.

Chemical (Fungicide FRAC Code)	Product Rate Per Application[a]	Product Rate Per Season	PHI[b] (days)	Target Diseases	Label Notes
Agricultural Streptomycin, Agri-Mycin 17, Harbour (25)	100-200 ppm (4-8 oz/50 gal H2O)	no limit	0	wildfire, angular leaf-spot, blue mold	Use low rate for prevention and higher rate when disease is first observed or in areas with a history of angular leaf-spot.
Actigard 50WG (P1)	0.5 oz	1.5 oz (3 apps.)	21	blue mold	Begin applications when plants are >18 inches[c] in height. Actigard *must be applied 4-5 days prior to infection* to allow for activation of plant defense compounds. *Do not apply to plants that are stressed* from drought or other environmental factors. Make up to 3 applications in at least 20 gal/A on a 10-day schedule.
Forum (formerly Acrobat) (40)	2-8 fl oz	30 fl oz	0	blue mold	Increase rate and application volume (20-100 gal/A) as crop size increases. Forum must be tank-mixed with another blue mold control product, such as mancozeb, for resistance management. Neither Ridomil Gold, Ultra Flourish, MetaStar, Revus, nor Actigard are recommended as tank-mix partners for Forum. Do not mix with surfactants, foliar fertilizers, or sucker control materials.
Revus 2.08SC (40)	8 fl oz	32 fl oz	7	blue mold	Begin applications before blue mold symptoms appear. Continue on a 7-10 day schedule. Make no more than two consecutive sprays before switching to a fungicide with a different mode of action (do not alternate with Forum). Addition of a surfactant (spreader/penetrator or non-ionic) may enhance activity.
Orondis Ultra premix (U15)	8 fl oz	32 fl oz	7	Blue mold	Use higher rates when disease is already present. Increase rate and spray volume (20-100 gal/A) as crop size increases. Rotate fungicides by mode of action, and do not use if Orondis Gold 200 was applied for black shank control
Orondis Ultra A (U15/U49)	2.0-4.8 fl oz	19.2 fl oz	7	blue mold	Use higher rates when disease is already present. Increase rate and spray volume (20-100 gal/A) as crop size increases. For resistance management, must be tank-mixed with ½ pt Revus; rotate fungicides by mode of action, and do not use if Orondis Gold 200 was applied for black shank control.
Presidio (43)	4 fl oz	8 fl oz	7	blue mold	Apply as a foliar spray prior to disease onset or at first sign that blue mold is in the area. For resistance management, must be tank mixed with another fungicide of different mode of action (FRAC class). A second application can be made with a minimum 7-day interval after the first application. Do not use if Presidio was previously applied for black shank control.
Quadris 2.08SC and generics (11)	6-12 fl oz	32 fl oz	0	target spot, frogeye, blue mold	Begin applications before blue mold symptoms appear. For blue mold, continue sprays on a 7-14 day schedule (use the shorter spray interval when conditions favor disease). If blue mold is present in the field, apply Forum tank-mixed with a mancozeb fungicide, Revus, or Orondis Ultra prior to using Quadris. Do not make back-to-back sprays, but alternate with a different fungicide labeled for tobacco. Can be used up to the day of harvest, but minimize post-topping application, as fungicide residues are a significant industry concern. Do not mix with EC-type pesticides or with sucker control materials.
Mancozeb (Manzate Pro-Stick, Penncozeb DF) (M3)	1.5-2 lb	no limit	30	blue mold, anthracnose	Mancozeb residues are an industry concern, so use this product only as a tank-mix with Forum or Presidio, alternated with Quadris, Revus or Orondis Ultra. To minimize the risk of high residue levels do not apply later than 7 weeks after transplanting. Only Manzate ProStick is labeled in most burley states, while Penncozeb DF and Roper DF Rainshield are labeled in VA.
Aliette WDG (33)	2.5-4 lb	20 lb	3	blue mold	Make first application immediately after transplanting; continue on a 7-10 day schedule. Increase rate and application volume (20-100 gal/A) as crop size increases.

[a] Rate range of product PER ACRE. In general, use the highest labeled rates when disease pressure is high. Refer to product label for application information, restrictions, and warnings.
[b] Preharvest interval.
[c] Actigard can be applied to dark tobacco varieties at the 12-inch stage.

Insect Pest Management

Hannah Burrack

Insect Management

Insect pests can attack tobacco from transplant through harvest. Hornworms and budworms reduce yields by feeding directly on plant leaves. Aphids cause indirect losses; their feeding reduces plant vigor, they may spread viruses, and sooty mold produced when large populations of aphids are present reduces tobacco quality. Flea beetles cause stress when feeding on young plants and directly damage harvestable leaf when feeding on mature plants. Tobacco insect pests are active at predictable times during the growing season (Table 1). Timely field checks and use of treatment guidelines will allow early detection and assessment of problems, so sound pest management decisions can be made.

Refer to the tables in this section for insecticides recommended for control of important pests of tobacco. A list of generic alternatives for some insecticides can be found in Appendix II, along with key safety information for different classes of insecticides.

Soil Insect Management

Wireworms. Wireworms are already present in the soil at transplanting. Eggs are laid on the soil in the summer and early fall of the previous year, and larvae can live in soil for several years. They damage tobacco by tunneling into the stalk below the soil surface. This may kill or stunt plants and may open even resistant varieties to soilborne diseases. Plant death, replanting, and stunting can result in an uneven, difficult-to-manage crop. Under good growing conditions, tobacco usually recovers from wireworm damage with no yield loss. However, if conditions are less favorable or if certain diseases are present, yield may be reduced.

It is not possible to control wireworms in tobacco with post-transplant rescue treatments; you must decide in advance whether you need to use soil-applied insecticides. If there is a history of wireworms, if the field was weedy or fallow, or if the field is heavily infested with soilborne diseases such as black shank and Granville wilt, a preventive treatment may be justified. In other cases, preventative management is not recommended. Insurance treatments for wireworms add to the costs of production, risk phytotoxic effects on plants, and add pesticides to the environment.

Either pre transplant soil applied insecticides (Table 2; Lorsban/Warhawk, Capture LFR) or systemic insecticides (Tables 3 and 4; Admire, Brigadier, Durivo, Platinum) can be used for wireworm control. Both types have provided good control in tests, but systemic materials also provide control of aphids and flea beetles. Use either a pre transplant or a systemic insecticide for wireworms, not both. Whether you choose a contact or a systemic, the proper application technique is important. Note that chlorpyriphos, the active ingredient in Lorsban and Warhawk has been under active EPA review in recent years. Check registration status and product labels before using products containing this material.

Table 1. Insect management calendar—treatment guidelines for key tobacco insect pests.

Insect	Treatment Guidelines
1-4 weeks after transplant	
Cutworms	Five or more freshly cut plants per 100 plants checked.
Flea Beetles	Four or more beetles per plant on new transplants, 10 or more beetles on 2-4 week-old plants,
3 weeks after transplant until topping	
Aphids	Colonies of 50 or more aphids on at least one upper leaf of 10% or more of the plants from three weeks after transplant until topping.
Budworms	Five or more budworms per 50 plants from three weeks after transplant until one week before topping.
Hornworms	Five or more hornworms (1 inch or longer) per 50 plants from three weeks after transplant until topping. Do not count hornworms with white cocoons on their backs.
Topping until harvest	
Hornworms	Five or more hornworms (1 inch or longer) per 50 plants. Do not count hornworms with white cocoons on their backs.
Flea Beetles	60 or more beetles on plants more than 4 weeks old.

Table 2. Pre- and post-transplant soil applications for tobacco fields.

Pre-plant Insecticides[1]	Rate/Acre	Labeled Post-transplant Pests
Lorsban Advanced (chlorpyrifos[2], IRAC 1A) (and generics)	2 pt	Cutworms, Wireworms
Brigade EC[2] Capture LFR[2] (bifenthrin, IRAC 3)	4 to 6.4 fl oz 3.4 to 8.5 fl oz	Cutworms, White grubs, Wireworms
Acenthrin (acephate + bifenthrin, IRAC 1B + 3)	16 oz	Cutworms, Armyworms, White grubs, Wireworms
Post-plant Insecticides	Rate/Acre	Labeled Post-transplant Pests
Orthene 97 (acephate, IRAC 1B)	0.75 lb	Cutworms, Vegetable weevils
Acenthrin (acephate + bifenthrin, IRAC 1B + 3)	8 to 16 oz	Cutworms, Armyworms, Vegetable weevils
Warrior II with Xeon Technology (lambda-cyhalothrin[2], IRAC 3)	5 to 9 fl oz	Cutworms, Armyworms, Tree cricket, Vegetable weevils, Webworms
Coragen (chlorantraniliprole, IRAC 28)	3.5 to 5 fl oz	Cutworms, Armyworms,

Broadcast and incorporate spray or granules according to label instructions immediately before transplant.

[1] Pre-transplant soil applications are only recommended for high risk fields and should be avoided when possible.

[2] Restricted use materials.

Table 3. Tray-drench application of insecticides.

Insecticide	Rate	Target pests
Admire 2F (and generic imidacloprid formulations) (imidacloprid, IRAC 4A)	1 fl oz/1,000 plants 1.4 to 2.8 fl oz/1,000 plants	Aphids, flea beetles (lowest rate), wireworms (high rate)
Admire Pro 4.6F (imidacloprid, IRAC 4A)	0.5 fl oz/1,000 plants 0.6 to 1.2 fl oz/1000 plants	
Orthene 97 (acephate, IRAC 1B)	3/4 lb/A	Flea beetles, cutworms
Platinum 2 SC (thiamethoxam, IRAC 4A)	0.8 fl oz/1,000 plants	Aphids, flea beetles (lowest rate)
	1.3 fl oz/1,000 plants	Wireworms
Verimark (cyantraniliprole, IRAC 28)	10 to 13.5 fl oz	Aphids (suppression), flea beetles

Pre transplant soil applied materials should be thoroughly incorporated. It is also important to give broadcast insecticides time to work before transplanting; at least two weeks are recommended, unless the label says otherwise. For systemic greenhouse-applied insecticides, apply materials evenly and wash them off thoroughly to move the insecticide to the potting soil. Transplant water treatments should only be applied if application equipment can be accurately calibrated. Pressurized tanks fitted with nozzles to apply transplant water treatments are advised, and growers are cautioned not to apply transplant water treatments using gravity flow tanks.

Other soil insect pests. Growers may have occasional problems with sod webworms. These caterpillars tunnel in the underground stem much like wireworms, but they are almost always found in the stem, and they line the cavity with silk. These strands of silk, covered by dirt particles, often hang out of the entry hole. Problems with webworms are rare but sometimes occur in fields recently converted from sod. Vegetable weevil larvae may also feed on tobacco seedlings and are light green legless grubs. Adult vegetable weevils may feed on tobacco leaves following transplant and are grey-brown with a v-shaped mark on their wings. Soil-dwelling pests can be controlled after transplant, but growers should note fields where damage has occurred to develop preventative management strategies the next time they plant tobacco.

Cutworms. Preventive chemical control is not recommended for cutworms. Cutworms are occasionally a problem post transplant, and effective rescue treatments are available. Growers can reduce the likelihood of cutworm problems by preparing the soil four to six weeks before transplanting and should scout fields for damage regularly during the first three to four weeks after transplant. Cutworm feeding first presents as small, webless holes on young leaves. As the larvae grow, they begin their typical cutting behavior. Cutworm larvae can be distinguished from other caterpillars because they curl into a circle when disturbed. Because most cutworm species are active only at night, suspected damage should be confirmed with evening observations to determine if caterpillars are present.

Treat with a foliar spray (Table 2) if 5 percent or more of the plants are damaged and live caterpillars are observed. Stand losses of 10 percent or less will not typically result in reduce yields. Fields are more likely to be infested if they were weedy the previous fall and winter or if they are low-lying with heavier soils.

Table 4. Transplant water applied insecticides.[a]

Insecticide	Rate	Target pests
Imidacloprid 2F formulations (many generic materials) (imidacloprid, IRAC 4A)	1.4 fl oz/1,000 plants	Aphids, flea beetles (lowest rate), wireworms (high rate)
	1.8 to 2.8 fl oz/1,000 plants	
Admire Pro 4.6F (imidacloprid, IRAC 4A)	0.6 to 1.2 fl oz/1,000 plants	
Coragen SC (chlorantraniliprole, IRAC 28)	5 to 7.5 fl oz	Budworms, hornworms
Durivo (thiamethoxam + chlorantraniliprole, IRAC 4A + 28)	0.6 to 1.6 fl oz/1,000 plants	Aphids, budworms, flea beetles (lowest rate), hornworms, thrips, wireworms
Orthene 97 (acephate, IRAC 1B)	3/4 lb/A	Flea beetles, cutworms
Platinum 2 SC (thiamethoxam, IRAC 4A)	0.8 to 1.3 fl oz/1,000 plants	Aphids, flea beetles (lowest rate)
	1.3 fl oz/1,000 plants	Wireworms
Restricted Use Pesticides		
Acenthrin (acephate + bifenthrin, IRAC 1B + 3)	16 oz	Flea beetles, cutworms, wireworms
Brigade 2E Capture LFR (bifenthrin, IRAC 3)	4 to 6.4 fl oz/A 5.3 to 8.5 fl oz/A	Cutworms, wireworms

[a] Either a greenhouse tray drench or a transplant water insecticide application should be made. Efficacy of these materials is not improved when multiple such applications are made, and multiple applications may results in plant injury.

Pre transplant: Tray Drench Applications

Tray drench applied neonicotinoid insecticides can provide long term control of flea beetles and aphids and can suppress wireworm injury (Table 3). Imidacloprid (most commonly used as Admire Pro 4.6F) and thiamethoxam (Platinum) are systemic insecticides labeled for application as a drench to float trays prior to transplant. It is important to note that formulations of the same active ingredient may have different rates. Read the label for the product you plan to use carefully to ensure that you are using the correct rate. The lowest labeled rate for your target pest is recommended. When applying, agitate or mix the insecticide frequently to keep it from settling in the tank. Plants should be watered from above after application to wash the insecticide from the foliage into the soilless media. Failure to wash the insecticide from the foliage may result in reduced control. Adverse growing conditions may cause a delay in the uptake of the product into the plants and delay control.

Transplant: Setter-Water Applications

Soil-applied insecticides labeled for use in transplant (setter) water include Admire Pro (or generic equivalents), Orthene 97 (or generic equivalents containing the active ingredient acephate), Durivo and Coragen (Table 4). Coragen is labeled for

caterpillar control only. When applied in transplant water, the active ingredient in Coragen and Durivo (chlorantraniliprole) will provide residual control of hornworms and budworms for between 4 to 6 weeks, depending upon environmental conditions. A minimum of 100 gal/A is recommended to ensure adequate distribution of pesticide solution in the root zone, and control may be improved with higher volumes of water used. With all transplant water treatments, it is important to ensure that the solution is evenly distributed for effective insect control. For application equipment that has minimal agitation, such as tobacco transplanters, give proper attention to mixing. Keep the water suspension agitated or mix regularly to avoid settling in the transplant tank. Adverse growing conditions may cause a delay in the uptake of Admire (or a generic equivalent) into the plants and a delay in control.

Premix dry insecticide formulations in water to form a slurry before putting it into the transplant water tank. If premixing is not done, allow time for the product to dissolve. Use of more than the label rate may result in some plant damage. Orthene 97 has a 2ee label for a transplant water tank-mix with Admire. See the label for more information.

Foliar Treatments for Tobacco Fields

The numbers of tobacco pests per plant or the percentage of infested plants in a field determines whether a control measure is justified. Pest numbers can vary due to factors such as weather, natural enemies, and transplant date. Early set fields are prone to attack by flea beetles and tobacco budworms, while late-set fields are at greater risk to aphids. Careful field monitoring is necessary to determine whether or not an insecticide application will provide an economic return through yield or quality protection.

The treatment guidelines listed in Table 1 allow proper timing of insecticide applications. Weekly field scouting is necessary to collect the information needed to use them. Check at least 100 plants per field—10 groups of 10 or five groups of 20 in up to 5 acres. Add two locations for each additional 5 acres of field size, up to 20 acres. Pick scouting locations randomly. Examine the plants carefully for damage or live insects. Record the counts, calculate the average, and compare them to the table values. Keep these counts so that trends in insect numbers can be spotted easily during the season.

Aphids

Aphid infestations begin when winged adults fly into fields and deposit live young on plants, which happens about four to six weeks after transplant. Offspring of these "colonizers" mature in seven to 10 days and begin to produce 60 to 70 live young each. Aphid numbers in infested fields double about every two to three days. In conventionally grown tobacco, *Aphids* can be managed via greenhouse tray drench or transplant water applications of products containing imidacloprid or thiamethoxam (Tables 3 and 4) or with foliar applications in the field (Table 5). If greenhouse or transplant water applications are made, additional field applications are rarely needed. Fields should be checked weekly by examining the bud area of 10 consecutive plants in at least five locations for colonies (clusters) of aphids on the underside of leaves. *Foliar applications should only be made if colonies of about 50 aphids are found on 10% or more of the plants that are examined.* Thorough coverage with sprays directed to the underside of leaves at the top of the plant is essential to obtain satisfactory aphid control. Aphid infestations tend to be higher when topping is delayed and in later-set fields, where more than minimum recommended rates of nitrogen are used.

Table 5. Green peach aphids.

Insecticides	Rate/A	Harvest Interval (days)
Actara 25% WDG	2 to 3 oz	14
Assail 30 G	1.5 to 4 oz	7
Admire Pro 4.6 F	0.7 to 1.4 fl oz	14
Fulfill 50 WDG	2.75 oz	14
Orthene 97*	3/4 lb	3
Voliam Flexi WDG*	2.5 to 4 oz	14
Restricted Use Pesticides		
Besiege*	5 to 10 fl oz	40
Brigade 2EC*	2.56 to 6.4 fl oz	Do not apply later than layby
Brigadier*	3.8 to 6.4 fl oz	
Capture LFR*	3.4 to 8.5 fl oz	
Endigo ZC*	4 to 4.5 fl oz	40
Lannate 90 SP*	½ lb	14

Materials indicated by * are associated with pesticide residue concerns by purchasers. If these are materials of choice, growers are strongly encouraged to communicate with potential buyers before treating to ensure that their use will not limit crop marketability.

Budworms

Budworms chew rounded holes in developing leaves of the upper third of the plant. Infestations tend to be greatest in the earliest-set fields in an area. Moths lay single eggs, so infestations are scattered randomly over a field. Examine the bud area carefully for the black ground pepper-like droppings, small holes, and caterpillars. Damage will increase as the budworms feed and grow. If the bud is destroyed, the plant will develop new terminal growth, but this injury is not common. Direct leaf damage and stunting rarely reduces yields. Examine the buds for feeding damage and the small green-to-black worms. *Treat if there are five or more live budworms (less than 1.25 inches long) per 50 plants and topping is more than one week away.*

Tobacco plants can compensate for budworm damage, so follow treatment guidelines to avoid unnecessary treatments. Do not count the plant as infested if you cannot find a budworm. Sprays are most effective if applied when larvae are small and actively feeding. Use 25 to 50 gal of water/A and spray in the morning or early evening when the bud area is open and the budworms are most exposed to sprays. A list of insecticides and restricted-use pesticides labeled for the control of budworms is available in Table 6.

Hornworms

Hornworms eat large amounts of tobacco foliage. The first generation typically occurs in June. A second generation is active from late July through late August. Weekly field checks will allow detection of infestations that would benefit from treatment. Examine the entire plant, particularly the upper third, for signs of damage and live worms. *Treat if there are five or more hornworms (1 inch or longer) per 50 plants and topping is at least one week away.* Treatments applied before most worms exceed 1.5 inches in length will greatly reduce yield loss. Hornworms with white egg-like cocoons on their back are parasitized by

Table 6. Budworms and Hornworms.

Insecticides	Rate/A	Harvest Interval (Days)	Comments
Agree WG (3.8% Bt aizawai, IRAC 11)	1 to 2 lb	0	This material contains Bt as the active ingredient and is more effective against hornworms than budworms.
Assail 30 SG (acetamiprid, IRAC 4A)	2.5 to 4.0 oz	7	Most effective against eggs and young larvae. Will not control large larvae.
Biobit HP (6.4% Bt kurstaki, IRAC 11)	½ to 1 lb	0	This material contain Bt as the active ingredient and are more effective against hornworms than budworms.
Coragen SC* (chlorantraniliprole, IRAC 28)	3.5 to 7.5 fl oz	1	
Dipel 10 G	5 to 10 lb	0	These materials contain Bt as the active ingredient and are more effective against hornworms than budworms.
Dipel DF	½ to 1 lb		
Dipel ES	1 to 2 pt		
Javelin WG, (*Bacillus thuringiensis*, IRAC 11)	1/8 to 1¼ lb		
Exirel (cyantraniliprole, IRAC 28)	13.5 to 20.5 fl oz	7	
Heligen (Helicoverpa zea nucleopolyhedrovirus ABA-NPV-U, IRAC 31)	1.2 to 2.4 fl oz	0	This material contains a live virus that infects budworm and closely related caterpillars such as corn earworm. It is most effective against small larvae and may require more than one application. **It is not effective against hornworms.**
Orthene 97* (acephate, IRAC 1B)	3/4 lb	3	
Blackhawk (spinosad, IRAC 5)	1.6 to 3.2 oz	3	Lower labeled rate recommended.
Voliam Flexi WDG* (thiamethoxam + chlorantraniliprole, IRAC 4A + 28)	4 oz	14	
XenTari DF (*Bacillus thuringiensis*, IRAC 11)	½ to 2 lb	0	This material contains Bt as the active ingredient and is more effective against hornworms than budworms.
Restricted Use Pesticides			
Acenthrin* (acephate + bifenthrin, IRAC 1B + 3)	8 to 12 oz	Do not apply later than layby	This is a premix product containing acephate and bifenthrin,
Besiege* (lambda-cyhalothrin + chlorantraniliprole, IRAC 3 + 28)	5 to 10 fl oz	40	
Brigade 2EC* (bifenthrin, IRAC 3)	2.56 to 6.4 fl oz	Do not apply later than layby	
Capture LFR* (bifenthrin, IRAC 3)	6.8 to 8.5 fl oz		
Denim (emamectin benzoate, IRAC 6)	8 to 12 fl oz	7	
Endigo ZC* (lambda-cyhalothrin + thiamethoxam, IRAC 3 + 4A)	4 to 4.5 fl oz	40	
Warrior II* (lambda-cyhalothrin, IRAC 3)	0.96 to 1.92 fl oz	40	

Materials indicated by * are associated with pesticide residue concerns by purchasers, particularly when used late in the growing season. If these are materials of choice, growers are strongly encouraged to communicate with potential buyers before treating to ensure that their use will not limit crop marketability.

a small wasp. These worms will not contribute to yield loss and should not be included in counts to determine economic thresholds. By late August or early September as much as 90% of the hornworm population may be parasitized.

Hornworms pose the greatest threat at the end of the growing season. Those present on plants at harvest will continue to feed on wilting and curing tobacco. Check fields for hornworms about one week before harvest. If an insecticide will be applied preharvest to prevent taking significant numbers of hornworms to the barn, be sure to avoid materials with residue concerns (Table 6). There are no treatments to control hornworms effectively on housed tobacco.

Flea Beetles

Tobacco flea beetles are present in every field each season. Damage tends to be most severe in fields that are set first, especially following a mild winter when beetle survival is greatest. Flea beetles move frequently, chewing small round holes (shot holes) in the leaves. Extensive damage can occur when beetles feed in the bud of the plant. This injury can add to transplant stress and slow plant establishment. Flea beetles can be controlled with systemic insecticides applied in the transplant water or by a foliar spray if a preventive treatment was not used. *An average of four or more beetles per plant is enough to cause significant damage following transplant. Treat if there*

Table 7. Tobacco flea beetles.

Insecticides	Rate/A	Harvest Interval (Days)
Actara 25% WDG (thiamethoxam, IRAC 4A)	2 to 3 oz	14
Assail 30SG (acetamiprid, IRAC 4A)	2.5 to 4 oz	7
Admire Pro 4.6F (imidacloprid, IRAC 4A)	1.4 fl fl oz.	14
Blackhawk (spinosad, IRAC 5)	1.6 to 3.2 oz	3
Exirel (cyantraniliprole, IRAC 28)	13.5 to 20.5 fl oz	7
Orthene 97* (acephate, IRAC 1B)	½ lb	3
Voliam Flexi* WDG (thiamethoxam + chlorantraniliprole, IRAC 4A + 28)	2.5 to 4 oz	14
Restricted Use Pesticides		
Acenthrin* (acephate + bifenthrin, IRAC 1B + 3)	8 to 12 oz	Do not apply later than layby
Besiege* (lambda-cyhalothrin + chlorantraniliprole IRAC 3 + 28)	5 to 10 fl oz	40
Brigade 2EC* (bifenthrin, IRAC 3)	2.56 to 6.4 fl oz	Do not apply later than layby
Brigadier* (bifenthrin + imidacloprid, IRAC 3 + 4A)	5.1 6.4 fl oz	
Capture LFR* (bifenthrin, IRAC 3)	3.4 to 8.5 fl oz	
Endigo ZC* (lambda-cyhalothrin + thiamethoxam, IRAC 3A + 4A)	4 to 4.5 fl oz	40
Warrior II* (lambda-cyhalothrin, IRAC 3A)	0.96 to 1.92 fl oz	40

Materials indicated by * are associated with pesticide residue concerns by purchasers. If these are materials of choice, growers are strongly encouraged to communicate with potential buyers before treating to ensure that their use will not limit crop marketability.

are four or more beetles per plant during the first two weeks after transplant. Flea beetles can also infest tobacco late in the growing season, close to harvest. This is much less common than early season infestation, and more difficult to control. The current threshold for flea beetles on fully grown plants is 60 per plant, but this is not backed by substantial research. Table 7 provides information on insecticides and restricted-use pesticides labeled for flea beetle control.

Occasional Pests

Armyworms may be present in no-till tobacco fields transplanted into burned-down grass or small-grain cover crop. Materials effective against cutworms and tobacco budworm will also be effective against armyworms.

Grasshoppers usually remain in hayfields and along waterways, but under dry conditions, they may move from these into tobacco when pastures or hayfields are clipped. Treatment of field borders to prevent mass migration into the field should be considered (Table 8). When selecting an insecticide for this use, consider the possibility of residues and time from application to cutting or grazing of hay. Treat when grasshoppers are active along field margins, or if 10 or more grasshoppers are found per 50 plants.

Table 8. Grasshoppers.

Insecticides	Rate/A	Harvest Interval (Days)
Orthene 97* (acephate, IRAC 1B)	1/4 to ½ lb	3
Restricted Use Pesticides		
Besiege* (lambda-cyhalothrin + chlorantraniliprole, IRAC 3 + 28)	5 to 10 fl oz	40
Brigade 2EC* (bifenthrin, IRAC 3)	2.56 to 6.4 fl oz	Do not apply later than layby
Capture LFR* (bifenthrin, IRAC 3)	3.4 to 8.5 fl oz	
Endigo ZC* (lambda-cyhalothrin + thiamethoxam, IRAC 3 + 4A)	4 to 4.5 fl oz	40
Warrior II* (lambda-cyhalothrin, IRAC 3)	0.96 to 1.92 fl oz	40

Materials indicated by * are associated with pesticide residue concerns by purchasers. If these are materials of choice, growers are strongly encouraged to communicate with potential buyers before treating to ensure that their use will not limit crop marketability.

Japanese beetles can feed on tobacco. The damage usually is confined to a small number of plants. Contact your local extension agent or specialist for specific management recommendations.

Stink bugs can feed on tobacco and cause the wilting or collapse of individual leaves, which can become scalded. Generally, the symptoms do not show until a day or two after feeding. The damage usually appears worse than it actually is, and plants often recover.

Thrips can feed on tobacco plants but usually are only a temporary problem. In other states, tobacco thrips and western flower thrips can transmit Tomato Spotted Wilt Virus to tobacco plants in the first month after transplant, but this pathogen is not a concern in the main burley and dark tobacco producing states. Several insecticides are labeled as foliar sprays for thrips control. Contact your local extension agent or specialist for specific recommendations.

Resistance Management

Repeatedly using insecticides with the same mode of action (MOA) can increase the risk of target pests developing resistance to these important tools. The Insect Resistance Action Committee (IRAC) has grouped insecticides sharing the same MOA into categories. The categories are listed following insecticide and formulation names in all tables in this section. To minimize the likelihood of resistance development, avoid successive treatment with insecticides having the same MOA.

Topping and Sucker Control

Andy Bailey, David Reed, and Bob Pearce

Introduction

The emergence of the flower buds in a tobacco crop signals a shift from a vegetative growth stage to a reproductive growth stage. Flower buds must be removed and suckers controlled to allow the crop to reach its full yield and quality potential at harvest. Timely topping and sucker control practices allow more efficient harvest when the crop reaches maturity.

Topping

Topping refers to the removal of the flower bud along with some of the uppermost leaves in order to stimulate growth and development of the remaining leaves. When left untopped or topped late, tobacco plants put energy into flower and seed production rather than leaf production, resulting in substantial yield losses. Topping removes the dominant influence of the terminal bud over lateral buds or "suckers," stimulating vigorous sucker growth that must be controlled. Topping also stimulates root growth, which increases nicotine production in the roots and translocation to the leaves. Secondary plant products that accumulate in the leaves and improve quality and smoking characteristics also increase after topping. Topped tobacco is much less prone to being blown over, since the plant is less top-heavy and root growth is enhanced.

Early topping reduces the populations of insects, such as aphids and budworms that are attracted to the terminal bud and flower. Early topping is also easier than later topping, since stalk tissue is softer and much easier to break. Later topping takes more time, in the removal of both the flower and suckers. Unless knives or clippers are used, tobacco topped late usually results in bruised, ragged stalks that are more susceptible to diseases such as bacterial soft rot (hollow stalk).

Most importantly, tobacco should be topped at a stage and height that will maximize yield and quality and satisfy the preferences of the buyer.

Topping Burley Tobacco

Bloom Stage

Research has shown that topping burley tobacco at 10 to 25% bloom generally provides the best yield and quality. This means that 10 to 25% of the plants in a field will have at least one open flower. Bloom stage at topping may also depend on the length of time the tobacco will remain in the field before harvest. Yields of burley tobacco topped at 75% bloom may be similar or better than tobacco topped at 10 to 25% bloom if harvested at three weeks after topping, whereas tobacco topped at 10 to 25% bloom and harvested six weeks after topping may have improved yield but lower quality.

Later-maturing varieties, such as KT 206, KT 209, N7371, and HB3307 may respond well to bud topping while bud topping may reduce yields in other varieties. NC 7, KT 210, KT 215, and HB4488 are extremely late-maturing varieties that require bud topping and may also require several leaves to be removed with the bud to prevent the plant from getting too tall in some seasons. Specific varieties may need early topping to produce their best quality. Early-maturing varieties such as KY14xL8, KT212, or KT219 that have more potential for high sucker pressure will also benefit from early bud topping to improve quality and improve management of suckers. Early topping will not affect yields if other factors, such as harvest time after topping, remain constant.

Leaf Number

Optimum leaf number for burley tobacco topping is generally 22 to 24 harvestable leaves. Some marketing contracts now encourage a true tip grade (T), and topping to this number of leaves allows the plant a better opportunity to produce a true tip. Yield effects of topping height are also dependent on timing of harvest. Tobacco topped to 24 leaves tends to yield slightly more than tobacco topped to 20 leaves and is more likely to have true tips. Too many extra leaves increase stripping labor and may increase the incidence of houseburn in older barns that have less space between tiers. Extra leaves beyond 24 do not necessarily mean extra yield. Root development dictates leaf production potential; therefore, extra leaves usually mean smaller leaves. Topping to the right number of leaves may require a slightly later topping time in order to produce tips. However, delays beyond 75% bloom will be counterproductive. A balance must be found between extra labor required to produce those leaves, the yield per acre, and premium for tips at the market.

Topping Dark Tobacco

Bloom Stage

Dark tobacco can generally be topped anytime between the elongated bud stage and 50% bloom without causing a significant impact on yield. Dark tobacco crops are usually more irregular than burley crops, with wide variations in bloom stage at the time of topping. It is not uncommon for some plants to have open flowers while other plants are at the early bud or even pre-bud stage. For this reason, it may be advisable to make two toppings. Attempting to make one topping on irregular crops lowers the yield potential of smaller plants. Increased yield incurred by allowing smaller plants to catch up usually compensates for extra labor required in making two toppings.

Leaf Number

Dark tobacco should be topped to 16 to 18 harvestable leaves. Topping to this height maximizes yield potential and allows a distinct characterization of lug and leaf grades that are desired by the industry. Plants topped to 12 to 14 leaves do compensate somewhat by producing larger leaves, but yield is still reduced by 200 pounds per acre or more compared to tobacco topped to 16 to 18 leaves. Lower topping to 12 to 14 leaves is only recommended for cigar wrapper crops.

Sucker Control for Burley and Dark Tobacco

Many of the benefits in topping at the appropriate bloom stage and leaf number are lost if suckers are not controlled. Suckers grow vigorously immediately after topping and can severely reduce yield and quality if not effectively controlled. Some varieties, such as KY 14xL8 and Narrowleaf Madole, are known to have more rapid sucker growth than other varieties

and may require more aggressive sucker control strategies. Three types of chemicals are available for controlling sucker growth on tobacco:

- **Contacts.** These chemicals are not absorbed by plants and must have direct contact with suckers and leaf axils, where they physically burn tender suckers.
- **Local systemics.** These chemicals must also have direct contact with leaf axils, but are absorbed into the plant at the leaf axil area and retard sucker growth by inhibiting cell division.
- **Systemics.** These chemicals do not have to come into direct contact with suckers. They are absorbed by the plant and move internally to leaf axil areas, where they retard sucker growth by inhibiting cell division.

In addition, some products (FST-7, Leven-38, Plucker Plus, and others) are mixtures of two of these chemical types.

Contacts

Contact chemicals contain fatty alcohols as the active ingredient and form a milky-white emulsion when mixed with water at the proper dilution. Contact chemicals are available under many trade names, such as Off-Shoot-T, Royaltac, Royaltac-M, Fair-Tac, Fair 85, Sucker-Plucker, Antak, and others. In University trials, all of these products have performed similarly when used under the same conditions. Fatty alcohols burn suckers that are shorter than 1 inch on contact, and sucker buds should turn brown or black within one to two hours after application. Fatty alcohols are rainfast at one hour after application and can be applied 24 hours before topping or within one day after topping. Contact chemicals will control suckers for five to 10 days. Any suckers longer than 1 inch will not be fully controlled and should be removed prior to applying fatty alcohols. Contacts should be applied so that the materials run down the stalk and come into direct contact with all leaf axils. Missed suckers are common with contacts applied to crooked or leaning tobacco, so it is a good practice to straighten crooked tobacco before application, if possible. The proportion of fatty alcohol to water is critical to the effectiveness of these chemicals. If the concentration is too weak, suckers will not be controlled, and if it is too strong, the suckers, leaves, and leaf axil will be burned and leaf loss could occur. A 3 to 5% solution is suggested on labels for contact chemicals. General recommendations are 3 to 4% solution for burley tobacco and 4 to 5% solution for dark tobacco, with the lower concentration used in initial applications and the higher concentration used in follow-up applications. For powered spray equipment, use 1.5 to 2.5 gal of contact chemical in 50 gal of total spray solution per acre (3 to 5% solution). For stalk-rundown applications with backpack or hand sprayers, a 3 to 5% solution is 12 to 19 fl oz of contact chemical per 3 gal of total spray solution. Use of agitation is recommended, since the fatty alcohols are lighter than water and will float on the water in the spray tank. Fatty alcohols should be added to the spray tank while adding water to promote dispersal. Avoid using cold water when mixing, as these products may not totally disperse.

Most contact products used in tobacco have been blends of 3 different fatty alcohols. Chemically, fatty alcohols are long, straight-chain alcohols that are referred to by the number of carbon molecules present. Examples of blended fatty alcohols include Off-Shoot-T, Royaltac-M, Fair 85 and Sucker Plucker. These products are blends of C_8, C_{10}, and C_{12} fatty alcohols. Since 2015, contact manufacturers have begun to market products, such as Royaltac and Antak, that only contain the C_{10} fatty alcohol. Research in 2015 and 2016 has shown that C_{10} fatty alcohol products provide sucker control that is equivalent to control from blended fatty alcohol products, and may be used at slightly lower rates than blended products (3 to 4% solution for burley and dark tobacco).

Local Systemics

Butralin, Prime+, Flupro, and Drexalin Plus are the local systemic products currently available. Butralin and flumetralin (Prime+, Flupro, and Drexalin Plus) are the active ingredients in these products. All belong to a family of chemicals called dinitroanalines and have similar use recommendations. When properly mixed with water, Butralin makes an orange emulsion, while flumetralin products make a yellow emulsion. Local systemics should be applied in a manner similar to application of contacts, so that the chemical runs down the stalk and contacts every leaf axil. Suckers longer than 1 inch should be removed prior to application. Local systemics do not burn suckers like contacts but rather stop sucker growth, with suckers remaining as a pale greenish-yellow tissue for several weeks after application. Applications of local systemics can be made with powered spray equipment or with backpack or hand sprayers.

Local systemics generally require three hours without rain after application to be effective. The activity of local systemics in stopping cell division can also cause distortion of small, upper leaves that come into contact with the chemical. For this reason, applications of local systemics should be delayed until upper leaves are at least 8 inches long. If upper leaves are less than 8 inches long and manual stalk rundown applications are made, direct the spray below these smaller leaves. If a local systemic is being applied alone, a rate of 1 gal/A should be used (1 gal/50 gal total spray solution or 8 fl oz (0.5 pt) per 3-gal spray solution). Local systemics, particularly those that contain flumetralin, are much more persistent in the soil than other sucker control chemicals, and severe damage can occur to subsequent crops, particularly grasses. For this reason, care should be taken not to use excessive amounts of these products. If manual stalk rundown applications are made with drop lines, backpack, or hand sprayers, care should be taken to prevent pooling of the solution at the base of the stalk. Use only enough solution to wet the stalk and suckers on each plant; 0.5 to 0.75 fl oz of spray solution per plant is sufficient. Reduced rates of local systemics can be used if tank-mixed with contacts or systemic products. Use 3 qt local systemic per acre when tank-mixing with contacts and 2 qt/A when tank-mixing with systemic sucker control products. Butralin and Flupro may only be applied once per season. Drexalin Plus may be applied twice per season, but at rates of no more than 0.5 gal/A per application. In North Carolina only, Prime+ may be applied twice per season at up to 0.5 gal/A per application.

In recent years, a precision manual application device known as a dosimeter has become available through Drexel Chemical Co. Dosimeters can be attached to droplines or backpack hoses to allow precise application volumes of up to 0.75 oz of solution. The dosimeters help control the volume applied to each plant and can be especially helpful when applying sucker control to

Table 1. MH product formulations **currently available**

MH product	Lb MH/gal liquid or % MH dry
Regular concentrate MH products	
Royal MH-30	1.5
Super Sucker Stuff	1.5
Fair Plus	1.5
High concentrate MH products	
Royal MH-30 Xtra	2.25
Sucker Stuff	2.25
Fair 30	2.25
Dry MH products	
Royal MH-30 SG	60
Sucker Stuff 80EG	60
Fair 80SP	60

Table 2. Sucker control, yield, quality grade index, and MH residue in tips of burley tobacco treated with recommended and reduced rates of MH—MSU West Farm, Murray KY, 2011

At topping	7 days after topping	% sucker control (0-100%)	Sucker Wt (lbs) per 30 plants	Total burley yield (lb/A)	Quality grade index (1-100)	MH residue in tips (ppm)
OST (2 gal/A)	RMH (1.5 gal/A) + Flupro (0.5 gal/A)	98	3.4	2620	57.4	89.8
OST (2 gal/A)	RMH (1 gal/A) + Flupro (0.5 gal/A)	93	5	2548	57	49.5

Abbreviations: OST = Off-Shoot-T, RMH = Royal MH 30 (1.5 lb/gal ai formulation). All treatments were applied using 60 gal/A of solution with TG-5 nozzles in 3-nozzles/row arrangement. Burley variety was NC 7. Tobacco was harvested approximately 5 weeks after topping (4 weeks after MH application).

small acreages of broadleaf wrapper tobacco with a backpack. The controlled volumes can help reduce the frequency of refilling the backpack sprayer while ensuring adequate applications for good control.

Systemics

Maleic hydrazide (MH) is the only true systemic product available for sucker control in tobacco. Since it is absorbed through the leaves and moves to actively growing sucker buds, it does not have to directly contact leaf axils to be effective. However, good soil moisture at the time of application is required to allow adequate absorption by leaves. Similar to other types of chemicals, MH does not control larger suckers, and these should be removed before application. MH should be applied as a foliar spray with powered equipment, since plant-to-plant stalk rundown applications do not allow enough leaf contact for adequate absorption into the plant. Absorption into the plant is also enhanced by using nozzles that produce coarse spray droplets as opposed to fine mist nozzles. Similar to local systemics, MH retards the growth of small upper leaves, and plants should be topped to a leaf no smaller than 8 inches long before MH is applied. MH products are available in three formulations: a regular liquid concentrate containing 1.5 lb MH/gal (Royal MH-30, Super Sucker-Stuff, Fair Plus), a higher concentrate liquid containing 2.25 lb MH/gal (Royal MH-30 Xtra, Sucker-Stuff, Fair 30), and a dry formulation (Royal MH-30 SG or Fair 80SP) that contains 60% MH by weight. Regardless of the formulation, the recommended rate of MH if used alone should be equivalent to 2.25 to 3 lb of active ingredient (MH) per acre (1.5 to 2 gal product per acre) and 1.5 lb to 2.25 lb ai per acre (1 to 1.5 gal product per acre) when used in combination with a local systemic. Product formulations and concentrations of all available MH formulations are shown in Table 1. Refer to product labels for specific use rates and other recommendations for each product.

The regular liquid concentrate (1.5 lb active ingredient/gal) is the most widely used form of MH in Kentucky, Tennessee, and Virginia and is the formulation discussed in this article unless otherwise noted. Regular-concentrate MH used alone can be applied at a rate of 1.5 to 2 gal/A. Recommended use rate for high-concentrate MH is 1 gal/A, which is equivalent to 1.5 gal/A of the regular concentrate. All MH formulations should be applied at a spray volume of 50 gal/A. MH is most effective if no rain occurs within 12 hours after application. If significant rainfall occurs within three hours after application, reapply at the full application rate. If rainfall occurs between three and six hours after application, reapply at one half the full application rate on the following day. If no rainfall occurs within six hours of application, MH does not need to be reapplied. There is an increased chance of leaf burning from MH if applied on bright, sunny days where the temperature is above 90°F. The optimum time to apply MH is on overcast or hazy days or in the morning during hot, clear weather. MH is more active in controlling sucker growth than other chemicals, and the most consistently effective sucker control programs include an MH application. In the past, it was common to use MH alone at the highest rate allowed for burley sucker control. However, there have been concerns in the industry about excessive MH residue on cured leaf, and major efforts have been made to reduce or even eliminate MH residues on burley tobacco. A mixture of MH at a reduced rate in combination with a local systemic is generally a better choice than MH alone. In addition, research has shown that MH applications made in the morning may result in lower MH residues on cured leaf than applications made later in the day.

MH and Local Systemic Combinations

An effective way to reduce MH residues without compromising sucker control is to use lower rates of 1 to 1.5 gal/A of regular-concentrate MH in combination with 2 qt/A of a local systemic applied with coarse nozzles. The combination with 1.5 gal/A MH consistently controls suckers as well as the full 2 gal/A MH rate and reduces MH residues. MH residue testing on cured leaf samples has shown that MH residues vary considerably from year to year and from one location to another (Table 2). The MH residue level of a particular cured leaf sample is influenced by the rate of MH applied, the amount and intensity of rainfall received after application, and the amount of time elapsed between application and harvest. To avoid high residue levels in cured leaf, use the lowest rate of MH that will provide acceptable sucker control, and allow at least 3 to 4 weeks between application and harvest. The lower 1 gal/A rate (regular concentrate) will reduce residues and has often provided sucker control that was equivalent to the 1.5 gal/A rate in research trials

(Table 2, Table 3, and Table 4). However, the 1 gal/A rate can be less consistent and give less than desired sucker control if the material is not properly applied or if applied during unfavorable conditions. Consistent success with reduced MH rates in combination with a local systemic requires application to tobacco which is straight, not under extreme drought stress, and in evenly spaced rows, using properly calibrated equipment and nozzles properly positioned above the row to give good stalk rundown.

Table 3. Impact of MH rate on cured-leaf MH residues by year and location for selected treatments from the regional burley sucker control trials

MH rate lb ai/A (gal/A)	TN1	VA	NC-LS	NC-R	KY
	Parts per million MH residue on cured leaves (average of all stalk positions)				
2010					
3.00 (2.0)2	75	34	48	129	123
2.25 (1.5)	45	18	25	56	105
1.50 (1.0)	23	10	11	35	42
2011					
3.00 (2.0)	76	26	48	118	--
2.25 (1.5)	56	14	17	64	--
1.50 (1.0)	23	10	15	54	--
2012					
3.00 (2.0)	24	18	40	66	108
2.25 (1.5)	15	14	16	57	50
1.50 (1.0)	10	11	13	20	26

[1] Locations for the regional sucker control trial include Greenville, TN; Glade Spring, VA; Laurel Springs, NC; Reidsville, NC, and Lexington, KY. Application methods differed by location but all were targeted to deliver 50 gallons per acre of sucker control solution.

[2] 3.00 lbs ai/A = 2 gallons per acre regular concentrate; 2.25 lbs ai/A = 1.5 gallons per acre regular concentrate; 1.5 lbs. ai/A = 1 gallon per acre regular concentrate.

Table 4. Impact of MH rate alone or in combination with a local systemic on sucker control and yield in burley tobacco averaged across four locations

Sucker control treatment	% Sucker control	Cured leaf yield (lb/A)
2011		
Check Topped No Sucker Control	0	2434
MH 3.00 lbs ai/A (2.0 Gal/A)	98.9	2813
MH 2.25 lbs ai/A (1.5 Gal/A)	99	2904
MH 2.25 lbs ai/A (1.5 Gal/A) + 1% FluPro (0.5 Gal/A)	99.2	2826
MH 1.50 lbs ai /A (1.0 Gal/A) +1% Flupro (0.5 Gal/A)	98.9	2733
2012		
Check topped no sucker control	0	2559
MH 3.00 lb ai/A (2.0 Gal/A)	95	2970
MH 2.25 lb ai/A (1.5 Gal/A)	93.7	2992
MH 2.25 lb ai/A (1.5 Gal/A) + 1% Prime+ (0.5 Gal/A)	98.4	2983
MH 1.50 lb ai /A (1.0 Gal/A) +1% Prime+ (0.5 Gal/A)	89.3	2836

Premixed Combinations

FST-7 and Leven-38 are prepackaged mixtures of MH and the contact n-decanol. Since both contain less MH (0.66 lb/gal) than other MH products, the maximum application rate is 3 gal/A. Reduced rates can be used if these products are tank-mixed with local systemics. They should be applied as a coarse spray with powered spray equipment in a spray volume of 50 gal/A to cover the top third to top half of the plant, allowing the solution to run down the stalk to the bottom of each plant. Since the active ingredients in both products tend to separate in the container, make sure the container is well mixed and shaken before its contents are added to the spray tank. Constant agitation in the spray tank should be used with FST-7, Leven-38, and all other sucker control products. Plucker Plus is a fairly new prepackaged mixture of flumetralin and a blend of three contact fatty alcohols that has recently been registered for use on tobacco. Plucker Plus contains less flumetralin (0.24 lb/gal) than other flumetralin products, so the maximum application rate is 2.5 gal/A. Up to two applications of Plucker Plus can be made per season, at 1.25 to 2.5 gal/A per application. Plucker Plus must be applied in a manner to achieve stalk run down of the material.

Application Methods for Sucker Control Chemicals

Four methods of application are currently being used to apply sucker control products to tobacco: powered spray equipment, drop lines, backpack or hand sprayers, and jugs.

Powered Spray Equipment for High Clearance, Over-the-Top Application

Use of powered spray equipment is the most labor-efficient method of applying sucker control products, as this method typically requires only one person and many acres can be covered in a day. Any type of sucker control product can be applied through powered spray equipment, although adequate coverage to achieve the best control generally requires high-volume spray output and straight, uniform tobacco. Coverage is the key to success with any sucker control application, particularly applications of contact chemicals and local systemics that must cover every leaf axil to be effective. Thorough coverage of all leaf axils requires a minimum of 50 gal/A spray volume, and coverage may improve on many crops as spray volume is increased to 60 or 70 gal/A. Pressure should be 20 to 30 psi.

Nozzle Arrangement

Broadcast applications and applications directed to the tobacco row are two types of nozzle arrangements that can be used. Broadcast or "straight-boom" arrangements using 20-inch nozzle spacing (for 40-inch rows) provide even coverage over the row and the row middle. Applications directed to the tobacco row involve multiple (three or more) nozzles per row. This method usually involves a nozzle placed directly over the row and two nozzles placed on either side of the row and directed at a slight angle into it. Broadcast applications usually provide the best coverage if tobacco is leaning or if row spacing is inconsistent, while directed applications may be preferred if tobacco is straight and row spacing is consistent. Even a slight misalignment of nozzles over each tobacco row with the

directed method can result in poor sucker control on those plants. Spraying only two or four rows at a time instead of using the entire boom can improve alignment with the tobacco. This is especially important if using reduced MH rates or no MH where stalk rundown is required. If no MH is used, directed applications with the 3-nozzle system may provide better sucker control than broadcast applications, provided tobacco is straight and row spacing is consistent. "Conveyor hoods" are funnel-type devices that can be attached to the spray boom over a 3-nozzle arrangement to "funnel" the spray solution through an opening aligned over the row in order to concentrate the solution down the stalk of plants. Field trials in Kentucky comparing sucker control and MH residue with conveyor hoods and standard 3-nozzle/row applications have shown no consistent benefits of conveyor hood applications, and reduced sucker control if tobacco is crooked.

Nozzle Selection

Nozzles that allow high output and produce coarse spray droplets are preferred for all sucker control applications. Coarse droplets tend to penetrate through the leaf canopy and reach all leaf axils down the stalk better than fine droplets. Full-cone nozzles such as TeeJet's TG-3, TG-4, TG-5, and TG-6, or their equivalents, are commonly used with powered spray equipment for over-the-top applications. The three-nozzle arrangement used for directed applications may be a TG-5 over the row and TG-3's on each side directed toward the row. Other nozzle combinations may also be effective. Broadcast applications can be made with all TG-3's or all TG-5's. Use TG-3's for more hilly terrain where traveling speeds are in the 2.5- to 3.5-mph range. For flatter ground where speed can be increased to 4 to 5 mph, use TG-5's or their equivalent to achieve the desired spray output.

Drop Line Applications

Drop line applications involve a high-clearance sprayer with hoses for each row attached to the boom. A spray trigger is attached to the end of each hose for operation by a worker walking behind the sprayer. Drop lines are used with plant-to-plant stalk rundown applications of contacts and local systemics. This method provides more direct sucker contact and generally provides better control than over-the-top applications but is labor intensive and requires a slower pace to accommodate workers. The speed of the sprayer can only be as fast as the slowest worker. Practice may be required for workers to become accustomed to the appropriate rate of application, particularly on crooked tobacco that may require directing the application to several areas on the stalk. On tall tobacco, missed suckers can be common in the top of the plant, but misses are less common than with other methods. Apply 0.5 to 0.75 fl oz of spray solution to each plant, with care taken to avoid applying excessive amounts that will pool on the ground at the bottom of the plant. Product rates per acre are the same as with any application method, although volume of spray solution required for drop line applications will be 20 to 40 gal/A depending on plant population and how straight the crop is, significantly less than the volume used in over-the-top applications. Drop lines work well for local systemic applications to plants with upper leaves smaller than 8 inches, since the applicator can direct the spray below these smaller upper leaves. Where applications are directed below small upper leaves, a second sucker control application should be made to those plants within seven days to cover leaf axils of upper leaves. Although slow and labor intensive, drop line methods are very effective in sucker control programs that do not include MH. Personal protective equipment (PPE) must be employed when using this application method. See Worker Protection Standard Updates, page 78, for more information.

Backpack and Hand Sprayer Applications

Backpack and hand sprayer applications are similar to drop line application methods, in that each worker applies 0.5 to 0.75 fl oz of spray solution to the top of each plant to run down the stalk. The backpack or hand sprayer consists of a small, 2 to 4-gal spray tank and a wand attachment that can be fitted with a coarse spray nozzle. This method may have an advantage over the drop line method in that each worker is independent of others and speed is not dictated by the slowest worker. Small-acreage growers using plant-to-plant stalk rundown applications prefer this method. See Worker Protection Standard Updates, page 78, for PPE requirements.

Jug Applications

Jug applications involve adding the chemical to a gallon jug with water and pouring 0.5 to 0.75 fl oz of solution down the stalk of each plant. One gallon of spray solution should treat 170 to 256 plants. Although the jug method is the simplest of all methods, it is more difficult to apply consistent amounts to each plant. Some small-acreage growers may still prefer the jug method. See Table 5 for conversion of product rates from gallons of product per 50 gallons of spray solution to ounces of product per gallon of spray solution. See Worker Protection Standard Updates, page 78, for PPE requirements.

Table 5. Conversion chart for gallons product per 50 gallon spray solution to fluid ounces product per gallon solution.

Gallons product per 50 gal/A solution	Fluid ounces product per 1 gallon solution
0.5	1.3
0.75	1.9
1	2.6
1.25	3.2
1.5	3.8
1.75	4.5
2	5.1
2.25	5.8
2.5	6.4
2.75	7
3	7.7

Chemical Topping of Burley Tobacco

"Chemical topping" refers to the concept of making a suckercide application to untopped burley tobacco that will effectively stop growth of the terminal bud and control axillary sucker growth without manual topping. If successful, this practice of chemical topping could save five man-hours per acre or more in manual topping costs. A three-year study was done on the feasibility of chemical topping of burley tobacco. This research showed that chemical topping was effective in eliminating the need for manual topping, without sacrificing yield (Table 6) or leaf quality, provided the following guidelines are used:

- Use a late-maturing variety such as KT 210 (which was used in this research), NC 7, HB4488, or KT 215. Timing of the suckercide application at the appropriate bloom stage is critical to

success with chemical topping, and later maturing varieties such as these take more time to progress through the bloom stages, allowing more time to make the application at the appropriate time. Early-maturing varieties such as KY 14xL8, KT 212, and KT 219 should be avoided for chemical topping.

- Make an application of MH (2.25 to 3 lbs ai/A, 1.5 to 2 gal/A regular concentrate MH) tank-mixed with local systemic such as Butralin or a flumetralin product (Prime+, Flupro, or Drexalin Plus) at 0.5 gal/A using standard application techniques when 10 to 50% of the plants in the field are at a pre-button stage when only the top of the flower head is showing between the leaf sheath of the bud. Tobacco may only be 4 to 5 ft. tall at this stage. This application timing will be approximately one week prior to when the tobacco would normally be manually topped at 10 to 25% bloom. Making the chemical topping application at timings later than 50% pre-button will likely allow continued elongation of the terminal bud, resulting in plants that are too tall to be manageable for harvest and housing.
- Tobacco will need to stand 4 to 5 weeks between the chemical topping application and harvest, which may be a few days longer than it would stand following manual topping.

Sucker Control Strategies for Burley Tobacco

Uniform Crops

For most crops that are uniform and can be topped one time, use 1 to 1.5 gal/A MH (regular 1.5 lb/gal formulation) with 2 qt/A of a local systemic as an over-the-top application with powered spray equipment. Top tobacco at 10 to 25% bloom and remove all suckers longer than 1 inch. Spray applications can be made within one day before or after topping. If upper leaves will be less than 8 inches long at topping, apply a contact at topping and then follow with 1 to 1.5 gal/A MH (regular 1.5 lb/gal formulation) plus 2 qt/A of a local systemic seven days later. Research has demonstrated that sucker control from contact applications can be more effective when applications begin just before topping.

Uneven Crops

The most common cause of sucker escapes is a delay in topping until suckers have reached a size that is difficult to control. Tobacco topped later than 50% bloom can have suckers near the top of the plant that are more than 1 inch long. These suckers will escape control if not removed by hand at topping, and a second application to these suckers will also result in poor control. This situation commonly occurs in uneven crops. One solution is to make two toppings. However, the best solution may depend on the degree of unevenness. Three strategies for uneven crops are:

- If the crop is not drastically uneven, the best approach may be to top all plants, leaving a small leaf (approximately 6 to 8 inches) at the top of plants that have not bloomed. Treat the entire crop with 1 to 1.5 gal/A of MH (regular 1.5 lb/gal formulation) and 2 qt/A of a local systemic. Use coarse nozzles only. To reduce labor, some producers may elect to top only those plants with a bud or bloom and spray the entire crop with the combination above, allowing the spray material to chemically top those plants in the pre-bud stage.
- In uneven crops that will require two toppings seven days apart, top plants that reach the elongated bud to early flower stage and apply a contact over the top to the entire field using powered spray equipment. Apply 1 to 1.5 gal/A MH (1.5 lb/gal formulation) plus 2 qt/A of a local systemic after the second and final topping.
- In extremely uneven crops that will require more than two toppings or two toppings more than seven days apart, top plants that are ready and apply contacts every five to seven days or at each topping using powered spray equipment over the top, or apply a local systemic at 0.75 gal/A with a contact or 1 gal/A alone as a manual plant-to-plant stalk rundown application only to topped plants at each topping. Flumetralin products (Prime+, Flupro, or Drexalin Plus) are the local systemics of choice in this situation, as they generally provide slightly longer control than Butralin. If a local systemic is used, do not retreat plants that have already been treated at a previous topping. At the final topping, apply 1.5 gal/A MH (1.5 lb/gal formulation) over the top using powered spray equipment.

Table 6. Burley total yield (lbs/A) from chemically topped treatments compared to manually topped tobacco. Data averaged over location (Princeton and Lexington KY) and year (2016 and 2017).

	Burley Tobacco Yield (lbs/a)	
Treatment	**Medium Maturity (TN 90)**	**Late Maturity (KT 210)**
Untreated*	2050	2232
Manually topped at 10% bloom**	2629	2890
Chemically topped at 10% pre-button**	2589	2789
Chemically topped at 50% pre-button**	2618	2602

* Untreated was topped but no sucker control treatment applied.
** Manually topped and chemically topped treatments received Royal MH-30 (1.5 gal/A) plus Butralin (0.5 gal/A).

Strategies for MH-free Burley Tobacco

Certain buying companies have offered price incentives in the past for burley tobacco that is not treated with MH. These incentives may be offered again, and some companies may only accept MH-free burley tobacco in the future. Although burley tobacco can be grown without MH, labor requirements may be greater and sucker control may be reduced in programs that do not include MH. If sucker control is adequate, some improvement in yield and cured leaf color can be seen in MH-free crops. Crops that have not received MH may also stay in the field longer before harvest. Alternative management and application techniques may need to be employed with MH-free tobacco. The most consistent method for producing MH-free tobacco is to use contacts and local systemics in plant-to-plant stalk rundown applications with drop lines or backpack/hand sprayers. As discussed previously, this method requires much more labor and time, and multiple applications are usually needed. Good yields and sucker control can be achieved in MH-free tobacco using over-the-top applications with powered spray equipment but achieving adequate coverage on all leaf axils can be difficult. For the best chance of success, use multiple contact applications (at least two) every seven days beginning before topping, followed by a single local systemic application at 1 gal/A either alone or preferably tank-mixed with a contact. Do not allow suckers to grow longer than one inch before treating.

Sucker Control Strategies for Dark Tobacco

Although sucker control strategies for dark tobacco are similar to those for burley, achieving effective sucker control is usually more difficult in dark tobacco. Sucker growth after topping is generally more vigorous than in burley, and ground suckers are more common. Dark tobacco is much more prone to blowing over and becoming crooked than burley. Also, dark tobacco typically stays in the field for a longer period between topping and harvest, requiring extended sucker control. The prostrate structure and leaf arrangement of dark tobacco is also not as conducive to achieving good coverage on all leaf axils. Some buyers of dark tobacco have discouraged the use of MH in the past except in situations of blow-over where stalk rundown is nearly impossible. MH used at topping or at high rates can cause severe upper leaf discoloration and distortion. For these reasons, plant-to-plant stalk rundown applications of contacts and local systemics with drop lines or backpack/hand sprayers are much more common in dark tobacco. Research has demonstrated that contact applications can be more effective when applications begin just before topping. As discussed previously, dark tobacco crops are rarely uniform enough to allow one topping over the entire field.

Table 7. Sucker control and yield from selected MH and MH-free spray programs in Dark Tobacco—MSU West Farm, Murray KY, 2013.

At 1st topping	At 2nd (Final) topping	7 days after 2nd topping	% Sucker control	Sucker Wt (lbs) per 10 plants	Total dark-fired yield (lbs/A)
OST (2 gal/A)	-	-	12	45.7	2080
OST (2 gal/A)	OST (2.5 gal/A)	OST (2 gal/A) + Butralin (0.75 gal/A)	74	27.9	2834
OST (2 gal/A)	OST (2.5 gal/A)	RMH (1 gal/A) + Butralin (0.75 gal/A)	88	13.7	2854
OST (2 gal/A)	OST (2.5 gal/A)	RMH (1.25 gal/A) + Butralin (0.5 gal/A)	92	14.6	2920
OST (2 gal/A)	OST (2.5 gal/A)	RMH (1.5 gal/A)	95	11.5	2903

Abbreviations: OST = Off-Shoot-T, RMH = Royal MH 30 (1.5 lb/gal ai formulation). All treatments were applied using 60 gal/A of solution with TG-5 nozzles in 3-nozzles/row arrangement. Dark variety was PD7309LC.

Plant-to-Plant Stalk Rundown Applications

A typical sucker control strategy for dark tobacco is to top plants that are ready (elongated bud to early bloom) and apply a contact at 4% solution (2 gal/50 gal total solution) to the entire field as a plant-to-plant stalk rundown application. Top the rest of the crop within seven days if possible and apply either a tank-mix of a contact at 4 to 5% solution (2 to 2.5 gal/50 gal total solution) with a local systemic at 3 qt/50 gal or a local systemic alone at 1 gal/50 gal. The contact/local systemic tank-mix allows a slightly lower rate of the local systemic to be used and may also increase sucker control compared to applying the local systemic alone at the full use rate. If more than two toppings are required, plan on applying a contact every seven days and follow with a local systemic or contact/local systemic tank-mix application at the final topping. If a local systemic is applied to plants that have not been topped or have upper leaves less than 8 inches long, direct the application below these smaller leaves. Another strategy is to apply a local systemic at 1 gal/A alone or at 0.75 gal/A as a tank mix with a contact at each topping. With this strategy, treat only plants that have just been topped and do not retreat plants at later toppings.

Over-the-Top Applications with Powered Spray Equipment

Although plant-to-plant stalk rundown applications are more common in dark tobacco, success can be achieved with over-the-top applications. Coverage on all leaf axils will be more difficult on dark tobacco, and slightly higher spray volumes can improve coverage. Spray volumes of 60 to 70 gal/A are recommended for contact and local systemic applications. Dark tobacco that is straight is rare, and crooked tobacco is usually the cause of missed suckers with over-the-top or plant-to-plant applications. If tobacco leans due to wind, try to straighten the tobacco before it grows crooked if possible, as this will improve coverage in over-the-top applications. If tobacco is relatively straight, directed applications with three nozzles per row will provide better coverage than broadcast, straight-boom applications. A good strategy for over-the-top applications is to apply a contact as a 4% solution at the first topping and again seven days later. Follow with a local systemic at 1 gal/A or contact/local systemic tank-mix as described previously. Since more suckers will escape control with over-the-top applications to dark tobacco, including an MH application is recommended (Table 7).

Use of MH in Dark Tobacco

Although MH use in dark tobacco has been discouraged in the past, buying companies have become more lenient in its use in recent years. The key to avoiding discoloration and distortion of upper leaves is to not apply MH at topping as is commonly done in burley. Allow at least five to seven days after the final topping before applying MH. Application rate is also important. Five to 6 qt/A (1.25 to 1.5 gal/A of the regular 1.5 lb/gal formulation) is recommended. Rates lower than 5 qt/A will provide marginal sucker control, and rates higher than 6 qt/A may cause some upper leaf discoloration, even when applied seven days after final topping. Recommended MH programs for over-the-top applications to dark tobacco are to apply a contact at the first topping and every five to seven days through the last topping. Five to seven days after the final topping, apply 5 to 6 qt/A regular concentrate MH alone or tank-mixed with 2 qt/A of a local systemic (Table 7). Tank-mixing of MH with a local systemic is recommended for improved and extended sucker control. If one topping can be made, apply a contact and follow with MH or MH/local systemic tank-mix five to seven days later. Be sure to top down to at least an 8-inch leaf.

Harvest Management for Burley and Dark Tobacco

Andy Bailey and Bob Pearce

One of the most important management decisions in producing high quality burley or dark tobacco is deciding when to cut. Maturity of the crop should be the primary consideration, although weather conditions and the availability of labor are also factors. Tobacco cut at maturity but not allowed to become overripe will be easier to cure and have better cured leaf quality than immature or over-mature tobacco. In general, burley or dark air-cured tobacco harvested by mid-September in Kentucky will have the best opportunity for good air-curing conditions in most years. Air-cured tobacco harvested later, particularly in October, will experience cooler temperatures, lower relative humidity, and generally less-ideal curing conditions in most years. Dark fire-cured tobacco can be harvested through mid-October if needed without reducing quality as outside weather conditions have less of an effect on curing conditions. Frost damage to tobacco is always a concern as harvest extends past mid-October. A worst-case scenario is when frost occurs on freshly harvested tobacco. If frost occurs on tobacco before harvest, it is advisable to allow tobacco to stand for at least two days following the frost. Often the first frost is light and does not occur on two consecutive nights.

Burley Tobacco

Burley tobacco should be allowed to ripen until nearly all the upper leaves show a distinct yellow-green color. Stalks and main leaf stems will lose much of their original greenish color and take on a cream-to-white appearance. This change in color usually occurs between three and five weeks after topping, depending on the variety and environmental conditions. Many growers hesitate to allow upper leaves to ripen for fear of losing lower leaves. However, added growth of upper leaves usually more than compensates for any loss of lower leaves. Under good growing conditions, burley tobacco crops will continue to add weight for the first four to five weeks after topping. Harvesting at six weeks or more after topping usually does not result in increased yields and often leads to decreased leaf quality.

If possible, try to schedule burley harvest when at least a few days of fair weather are expected. Burley tobacco can be cut and put on sticks ("speared" or "spiked") in the same operation. Do not put more than six plants on a stick unless plants are extremely small. Tobacco can then be left on the standing stick in the field to wilt before being picked up for housing. Tobacco that is adequately field wilted will be lighter and easier to handle and house (up to 20% less fresh weight), and will incur less leaf loss and bruising. Tobacco that sunburns or has light frost damage may require a few (three to four) days of sunlight to remove chlorophyll staining. It is especially important not to let harvested tobacco get excessively wet and muddy in the field, and it should not be left standing in the field longer than four days, even if weather conditions are good.

Burley tobacco can be loaded onto flatbed wagons or scaffold wagons for transport from the field. Flatbed wagons can be used if tobacco will be housed immediately. Tobacco loaded onto scaffold wagons can remain on the wagon for additional wilting prior to housing if needed. While loading, tobacco can be regulated on sticks so that plants are spaced equally apart and leaves hang straight down the stalk. Some producers prefer to regulate tobacco when housing.

Good housing practices are essential for high-quality cured tobacco. Good cured leaf can be obtained in conventional curing barns or in outdoor curing structures if proper management is used. In conventional curing barns, all available space should be uniformly filled, as air does not circulate well through tobacco in partially filled barns. Sticks should be spaced at least 6 inches apart on the tier rail in conventional barns to allow air movement between sticks. Ensure that plants are spaced equally on sticks and leaves are shaken out to hang down the stalk if that was not done at loading in the field. Fill each bent in the barn completely from top to bottom. If possible, fill the entire barn in the same time period, as greener tobacco does not cure as well when hung with partially cured tobacco. Tip leaves should hang between sticks of lower tiers and not overlap.

Burley tobacco can usually be hung at higher densities in open-sided, low-profile outdoor curing structures without increased risks of houseburn or barn rot. Burley tobacco hung on these structures can be spaced as close as 4 inches apart. Since natural airflow is greater in these structures than in conventional barns, closer stick spacing helps to prevent the tobacco from drying too fast and setting undesirable colors in the cured leaf. Burley tobacco cured with good management practices on outdoor curing structures has been shown to have cured leaf quality equivalent to burley cured in traditional barns in most curing seasons. Generally, burley cured on outdoor structures may have better quality than burley cured in barns during dry curing seasons, but may have lesser quality in wet curing seasons.

Dark Tobacco

Similar to burley tobacco, dark tobacco that is allowed to ripen before harvest will cure much more easily and with a better color. Dark tobacco does not show distinctive yellowness in the field at maturity like burley and is therefore more difficult to estimate ripeness. Dark tobacco is ready for harvest when leaves begin to show a very faint spotty yellow cast. At this stage, the upper leaves will be thick and oily and will crack readily when doubled between the fingers. Depending on variety and environmental conditions, this usually occurs between five and seven weeks after topping. Exceptions are TN D950 and PD 7305LC, two early-maturing varieties that may be ready for harvest between four and five weeks after topping. TR Madole, VA 309, and KT D6LC (which is a hybrid of KT D4LC and TN D950) may also show rapid maturity and leaf breakdown as early as five weeks after topping when transplanted in May.

Dark tobacco that is ripe when harvested will have brittle leaves that will break and bruise easily. For this reason, dark tobacco should not be cut and put on sticks in the same operation, as is typically done with burley. Due to its more prostrate leaf structure, dark tobacco should be carefully cut, with caution being taken not to break lower leaves, and allowed to

wilt in place or "fall" before being put on sticks. Depending on temperature and sunlight intensity, this wilting period may take anywhere from 30 minutes to several hours. Tobacco cut late in the day can be left to wilt overnight if there is no chance of rain that will leave the tobacco excessively wet or muddy. Once tobacco is wilted enough to be put on sticks without breaking leaves, it should be spiked and picked up as soon as possible. Dark tobacco is very susceptible to sunburn. Caution should be taken to avoid cutting more tobacco than can be spiked and loaded in a day. Many growers may pile the tobacco after initial wilting in groups of six plants to make spiking easier and temporarily reduce the risk of sunburn. No more than six plants should be put on a stick, and five plants per stick works better for larger tobacco. Whether the tobacco is spiked from piles or directly from the ground, it should not be allowed to stay in the field for more than a few hours before being picked up and loaded. Recently, some growers have used burlap sheets placed over piles of spiked tobacco before picking up to increase wilting and reduce the risk of sunburn. While burlap covering of piles will delay sunburn risks, be aware that dark tobacco can still sunburn under burlap on a clear, hot day. When loading, space plants equally on sticks and shake leaves so that they hang straight down the stalk.

Scaffold wagons are the preferred means of loading and transporting dark tobacco. Scaffolded tobacco is less likely to sunburn and can remain on the wagons for several days of additional wilting before housing if wagons are placed in shade or are covered with shade cloth.

Dark tobacco housed in newer barns with wider vertical tier spacing should have a stick spacing of at least 8 to 9 inches. In older barns with narrow tier spacing, place sticks at least 12 inches apart. Narrow tier spacing in older barns may only accommodate tobacco topped to 12 or 14 leaves, whereas wider tier spacing in newer barns will accommodate tobacco topped to the current market standard of 16 to 18 leaves. Use alternating placement on tier rails so that tobacco does not overlap tobacco on lower tiers, or hang tobacco only on every other tier if barn space allows.

For dark fire-cured and dark air-cured tobacco, fill the entire barn in the same time period, as tobacco will not cure as well when housed at different stages. Fill each bent of the barn from top to bottom, ensuring that plants are spaced evenly on sticks and leaves hang straight down the stalk. Due to increased risk of weather damage, the use of outdoor curing structures for dark air-cured tobacco is generally not recommended.

Cigar Wrapper Tobacco

There has been a steady demand for cigar wrapper tobacco in traditional dark air-cured and dark fire-cured types, as well as a new demand for cigar wrapper from non-traditional air-cured types (Connecticut Broadleaf and PA type 41) in burley and dark tobacco production areas. Harvest of tobacco intended for use in cigar wrapper markets requires very careful management to avoid damage to leaves. Cigar wrapper tobacco should be harvested when generally immature by most dark tobacco standards (two to four weeks after topping) so that leaves are thin and smooth. Workers harvesting cigar wrapper tobacco should be trained in the importance of preventing damage to leaves at harvest and handling. Tobacco should be carefully cut at ground level so that stumps are not left that could tear leaves. Cigar tobacco should be field-wilted for a short period of time like dark tobacco, with cut plants placed in the row middle instead of on the row where damage from cut stalks is more likely. Tobacco that is harvested immature can also be more likely to sunburn, so extra care should be taken to avoid sunburn during field wilting. Once plants are put on sticks, the sticks should be immediately loaded onto scaffold wagons and placed in the shade or under shade cloth until housed in the barn. See Cigar Wrapper Tobacco Production, page 71, for more information.

Facilities and Curing

Andy Bailey

Conventional Barn Renovation and Remodeling

Curing facilities are a concern for producers wanting to expand their production. With the high cost of new barns, renovation and remodeling of existing barns are an economic option. Curing barns that are generally in good structural condition, with some remodeling, can be improved to make housing easier and/or to aid the curing process.

Good burley curing requires natural air movement. Ventilator doors or equivalent openings equal to one-fourth to one-third of the barn side wall area should exist to permit natural air to enter and pass through the hanging tobacco. Keep the ventilator doors in good repair so they can be opened and closed as required to regulate ventilation and manage the cure. Whenever possible, remove obstructions such as trees, bushes, and hay stacked in attached sheds that may block prevailing winds.

Where possible, install full-width driveway doors in shed areas to allow wagon access and increase housing efficiency. Several growers still hand tobacco from the driveway across to the sheds and up into the barn, which adds a worker or two and costly labor hours.

Consider fans where natural ventilation is inadequate. Supplemental fan circulation and/or ventilation can help wilt green tobacco, aid curing of tightly housed tobacco in humid weather, help reduce mold growth on curing tobacco in wet curing seasons, and aid air movement in barns with poor ventilation. See the following publication on the selection, installation, and use of fans in tobacco barns (AEN-69, *Using Fans in Conventional Burley Barns*).

Many producers have found that in older dark tobacco barns, where tiers are only 3 to 3.5 feet apart vertically, better curing results when tobacco is housed on every other tier rail. This method eliminates overlapping and improves air movement. Sticks can usually be placed closer together when the plants do not overlap, thus compensating for barn capacity lost from the omitted tiers. Tier rails should not be overloaded. This could cause the rails to break or reduce air movement through the tobacco.

Structurally sound conventional barns can be modified for two- or three-tier, air-cure housing; cable hoist; or portable frame housing to obtain labor-saving benefits. Specific details of these procedures are contained in other publications.

What Type of Tobacco Barn or Curing Facility Should You Build?

There are several options for new tobacco barn construction as well as field curing structures. Consideration should include the most suitable facility for present and future production methods. With declining labor sources and increasing costs, laborsaving features are a must. Rising material and construction costs continue to increase the initial investment costs. A barn is the largest single investment required in the normal tobacco (burley or dark) production system. Mechanization trends affect whether a facility should be modified, will soon become obsolete, or is needed at all. Partially enclosed barns and plastic-covered field curing structures are alternatives for lower cost tobacco housing and curing. Field curing structures, especially, minimize both initial investment costs and hanging labor requirements, but may require more management for proper curing and are more susceptible to tobacco damage in strong winds.

Producers considering a new facility should certainly not favor the historic tall, labor-intensive barns from the past era of plentiful, low-cost labor and inexpensive homegrown lumber. Likewise, builders should not contend that they can only build barns of that type.

Considerations for Building Barns (fixed-roof structures)

When planning new fixed-roof curing facilities, producers should consider the following options:

- Basic three- or four-tier barn designs, two-tier economy designs, or one-tier field structures in which tobacco housing can be accomplished with a smaller crew and less total labor
- Alternative designs that use portable frames or cable-hoist mechanical handling and housing can save over half of housing labor costs
- Structures that permit other farm uses of the facility during the non-curing season, such as machinery and supply storage
- Future modifications for different tobacco housing and curing methods or other farm enterprises, as these methods could change significantly in the future

Considerations for Outside Field Curing Structures (plastic-covered structures)

Outside curing structures can be constructed at a much lower cost (for the same curing capacity) than barns, so they should be given consideration if curing capacity expansion is needed. They also require considerably less labor for hanging because they are only one tier high, and they have reduced safety concerns because workers do not need to climb to multiple tier heights. However, there are other considerations when using outside field curing structures.

- Curing quality has generally been found to be equal to or better in outside curing structures than in traditional barns.
- Tobacco on the outside of the structure is subject to increased damage from weather.
- Tobacco can be in case more readily than tobacco in traditional barns.
- There is additional labor and expense related to covering the structures with plastic, negating some of the advantage in labor efficiency over traditional barns.
- There is a risk of damage to the plastic cover and the tobacco from strong winds.
- The space requirements for outside field curing structures are substantial, generally about ¼ acre (including space for maneuvering) for every 1 acre of curing capacity.
- There are maintenance issues to consider (mowing, etc.).
- Portable curing structures can help minimize the distance from the tobacco field to the curing structure, encouraging better rotation practices. But, they have considerably higher costs, require a lot of extra effort to move and set up, have high space requirements for storing during the off season, and it can be more difficult to secure the plastic cover.

Designs and Plans

Numerous designs with plans and publications related to curing facilities are currently available on the UK Department of Biosystems and Agricultural Engineering website: http://www.bae.uky.edu/ext/tobacco. General groupings include the following:

- Three-tier and four-tier air-cure, 32, 40, or 48 feet wide, post-pier or pole-type construction, wood, or metal siding
- Two- or three-tier forced-air, 32 or 40 feet wide, wood or metal siding, pole-type construction
- Three-tier, 32 feet wide, pole rafter type, long tier fire-curing barn
- Open-interior air-cure barn with portable curing frames handled by tractor forklift
- Two-tier, partially enclosed air-cure barn, pole-type construction
- Cable-hoist mechanical housing system for new or modified air-cure barns
- Thirty-foot-wide machine shed with removable tier rails for small air-cure barn, pole-type construction
- One-tier, plastic-covered field curing structures with manual or mechanized housing
- Pallet rack components used as one-tier, plastic-covered field curing structures
- Stripping rooms attached to barns or freestanding, especially layouts for the new big-bale operations

In addition, there are also plans available for 32- to 36-feet wide cross-tier design barns for air- and fire-curing. Cross-tier design barns have become very popular in the dark tobacco production areas of western Kentucky. Most fire-curing barns that have been built in the last fifteen years have been cross-tier design.

Facility Design and Location

A barn should be in an open, well-drained area, on a high point on the farmstead with the broad side facing the direction of the prevailing wind to provide the best cross ventilation. Width is the most important dimension affecting ventilation, since it determines the distance the air must move as it passes through the facility and the tobacco. Traditionally, barns have

been 32, 40, or 48 feet wide and as long as needed to hold the desired amount of tobacco. However, very large, high capacity curing barns have been built in recent years for large tobacco operations. For these barns, which may be 80 feet wide, it is especially important that all possible measures be taken to maximize cross ventilation. It is difficult to get sufficient air movement through the tobacco for proper curing in the center of such large barns. It is important that other tobacco barns or farm structures that could block the wind not be located close to these large barns. Regardless of the measures taken to maximize cross ventilation, houseburn may still be a problem in the central sections of such large barns. If that is the case, consider adding fans to supplement natural ventilation. Fans can be used in barns to improve circulation and fresh air exchange through the tobacco to improve curing. Also, not operating fans during drier weather can reduce air exchange and maintain better humidity conditions. For fire-curing barns, the overall barn size determination should consider the size of the labor crew and how quickly they can harvest and house the tobacco to fill the barn. Ideally, a fire-curing barn should be filled within a two-day period to allow yellowing to proceed at approximately the same rate and allow subsequent firing practices to be the same throughout the entire barn. For this reason, many fire-curing barns hold no more than 4 to 6 acres, even on larger operations.

Lumber of sound quality and proper strength should be used for construction as shown in typical plans. For labor savings in housing, the "sheds" of barns should have driveway doors so transport vehicles can pass under the tier rails for efficient handing of tobacco up into the tiers. In air-curing barns, ventilator openings should have doors or panels that open, generally vertical in orientation, and equivalent in area to at least one-fourth to one-third of the sidewall area. Air-curing barns are being built with metal siding that do not have adequate sidewall ventilation. Inadequate ventilation will result in houseburn during humid weather or with tightly spaced tobacco. Air-cured tobacco should not be housed and cured in a fire-curing barn.

Lower cost plastic-covered field structures can use untreated wood for a reduced life or preservative-treated wood for a longer life. Various wooden and wire strung designs exist for stick harvested or notched plant hanging and curing. Careless and haphazard construction, including failure to adequately anchor high tensile wire, can result in failure of these field structures when fully loaded with harvested tobacco. Contrary to barns, field structures should be in protected areas, as they tend to have ample air movement through the tobacco but are subject to damage from very strong winds. Locate field structures beside barns or downwind from fencerows or tree lines to help protect them from strong winds.

Costs and Labor Efficiency

Curing facility initial costs can range from $1,500 per acre of capacity for simple field curing structures with plastic covers to $10,000 or more per acre of capacity for conventional air or fire-curing barns. Field curing structures will also have additional costs each year for the plastic covers, approximately $200 per acre. Useful life of these structures can vary from seven to 10 years for low-cost field structures to 40 or more years for well-built barns. Labor requirements for hanging tobacco in these facilities (not including harvesting and hauling) can vary from approximately 12 worker-hr/A of capacity for the single-tier height field structures up to 30 to 35 worker-hr/A for the tall, traditional barns (hanging labor requirements increase with barn height).

The amortized value of construction cost and labor for these facilities over their useful life is estimated at approximately 8 to 12 cents per pound of cured burley tobacco per year. The annual costs per pound of cured tobacco are even greater to repay short-term construction loans.

Air-Curing Burley Tobacco

One of the most important functions of any tobacco curing facility is to provide an environment for proper tobacco curing and management. The process of air-curing burley and dark tobacco changes chemical and physical properties of the leaf from the green and yellowish stages to tan and brown aromatic leaf for processing. Most of the changes occur during the first four weeks of curing (approximately two weeks for yellowing, two weeks for browning) and alter many compounds in the green leaf.

Cured leaf quality of air-cured tobacco is heavily influenced by the weather conditions during the curing season. Quality is influenced by moisture and temperature conditions inside the facility during the curing period. For several decades, the best conditions for curing burley have been cited from Jeffrey (1940) as a daily temperature range from 60 to 90°F and a daily relative humidity average of 65 to 70%. The study was based on airflow of 15 feet per minute (1/6 mph velocity) through tobacco in test chambers. These conditions were for tobacco grown and cured in the 1940s, which was a very thin, buff-colored leaf referred to as "white burley." Changes in varieties, fertility, and cultural practices in the last couple of decades as well as buyer preferences have resulted in a darker brown to red, thicker leaf now being preferred. Recent barn and chamber studies have indicated that steady or daily average relative humidity in the 72 to 75% range produces the tobacco currently desired by the industry, thus a higher daily average humidity than that of the historic study.

During late August through September, the typical tobacco air-curing season in Kentucky, the outdoor temperature is seldom above 90°F or below 60°F for any extended period of time. Relative humidity can dwell near 100 percent during heavy dew or foggy nights and briefly drop below 40 to 50% during the heat of the day, thus averaging around 70 to 75%. Cooler October temperatures can often be below 60°F for an entire day and/or several consecutive evening periods, with humidity ranging from 25 to 30% in daytime to not over 70 to 80% in evening hours, resulting in daily averages of 45 to 55%. Extensive curing studies by Walton, et al. (1971, 1973) on the effect of several combinations of low and high temperatures and relative humidity on the quality of burley can be summarized as follows:

- Low temperatures result in green leaf, regardless of the relative humidity and airflow. Chemical conversions are too slow at low temperature. The drying rate determines the degree of green cast in the leaf. The higher the drying rate, the greener the cured leaf.
- Low humidity and moderate temperature result in greenish or mottled leaf.

- Low humidity and high temperature (75°F and above) cause "piebald" (yellowish) leaf.
- High humidity and moderate-to-high temperatures for extended periods is "house-burning" weather. Houseburn results in a dark leaf with significant loss in dry weight. The weight loss is primarily caused by microbial activity which causes soft rot.

Undesirable colors that prevail in the cured leaf during improper curing are determined by temperature; however, it is relative humidity (if airflow is adequate) that determines the degree of damage incurred. Walton et al. (1973) showed that the greater the departure from the optimum relative humidity range, the greater the damage to the quality of the tobacco.

Control of the curing process is affected by spacing of the tobacco in the curing facility and management of the drying rate. Spacing can vary from 5 to 6 inches between plants or sticks for one- and two-tier facilities to 7 to 10 inches for three- to five-tier barns with tobacco overlapping on close-tier rails. The drying rate is managed primarily by operating the ventilators, plastic covering, or other air control means to regulate the ventilation rates.

The air conditions inside the barn generally follow the conditions outside, depending on the quantity of air movement and buffering action of the tobacco mass. The average temperature inside the barn will be slightly lower than outside because of evaporative cooling during the drying stage. The average relative humidity inside will be higher than outside under most conditions of adequate ventilation because of moisture moving out of the tobacco. A good way to determine the conditions inside the barn and that of the tobacco is to purchase a couple of commercial digital temperature and humidity instruments. Place these in the tobacco mass (but not directly against a moist leaf) to sense and record the environmental conditions. These instruments store maximum and minimum data readings that can be viewed to see past cycles of conditions, and can be reset as desired. The accuracy of relative humidity measurement is generally plus or minus 3%, which is reasonable for the price of these units.

An electronic, interactive tobacco curing advisory tool developed in a collaborative effort by the Department of Biosystems and Agricultural Engineering and the Kentucky Agriculture Weather Center at the University of Kentucky uses real-time data from the Kentucky Mesonet system, now in 77 counties, to produce a summary of average weather conditions (temperature, relative humidity, and wind conditions) for the previous 48 hours, and forecasts conditions for the coming 24 hours. Growers select their county, and the advisory summarizes weather conditions for that specific location and advises opening and closing ventilators, and in extreme conditions, adding supplemental ventilation or moisture. The advisory, which is available during the curing season from mid-July through the end of October, can be accessed at http://weather.uky.edu/burley_curing.html.

One-tier field curing structures with plastic covers normally have plentiful air movement through the tobacco, thus curing as well as the natural weather allows. Such structures should be placed downwind from fencerows or similar wooded areas to give protection from strong winds that can damage the plastic covering and tobacco. Plastic or other covering should be applied over the hanging tobacco before a significant rainfall and maintained throughout the cure for protection from rain and wind damage.

Dark Air-Cured Tobacco

Dark air-cured tobacco is cured essentially the same as burley, but because of the heavier body of dark tobacco, it is more prone to sweat, houseburn, and mold. Barns are used for dark air-cured tobacco, as one-tier field curing structures are not currently recommended due to increased potential for weather and wind damage. Barns used for dark air-cured tobacco are usually somewhat less open than many older barns used for burley, but still have workable ventilators to allow for adequate air flow. Under warm conditions (mean daytime temperatures above 80°F and mean nighttime temperatures above 60°F), barn doors and ventilators should be open during the early stages of curing to promote airflow through the tobacco. If warm, moist weather conditions prevail after housing, it may be beneficial to use some type of heat to aid the curing process. Heat may also be necessary following late harvests if cool (mean daytime temperatures below 65°F), dry conditions persist after housing. Heat sources that can be used include gas burners, coke stoves, or even small wood fires ("open-firing") using dry wood that produces little smoke, such as sycamore. For dark air-cured tobacco, it is extremely important that these heat sources be virtually smoke-free so as not to leave any, or very little, smoke residue on the leaves. Barn temperatures during heating should be kept low (not exceeding 100°F), as too much heat can cause excessive drying (Bailey 2006a). Growers should be aware that the use of heat in dark air-cured tobacco can be of benefit in the situations described above, but heat in dark air curing is not a necessity. Dark air-cured tobacco harvested by mid-September in western Kentucky is normally exposed to the best curing conditions and should not require the use of heat. Dark air-cured growers should refer to contract specifications and recommendations and comply if there are any restrictions against the use of heat during curing.

Dark Fire-Cured Tobacco

The fire-curing process for dark tobacco can be broken down into four phases: yellowing, color setting, drying, and finishing.

Although fire curing is still more art than science, with many slight variations in practices, the following are some basic, general guidelines for these phases:

Yellowing. The degree of yellowing that occurs in the tobacco before fires are started will affect the color of the cured leaf. Tobacco should be allowed to yellow as much as possible without heat, managing ventilators carefully to prevent houseburn and sweating. Firing should begin when yellowing is nearly complete (yellow spots appear or most of the leaf lamina has reached a solid yellow color). This usually occurs five to eight days after housing. Initial fires should be around 100°F. Fires that are too hot too soon will cause "bluing" of the tobacco, which results in a crude, green color that will remain after curing is completed. Top ventilators are usually left open during this phase of curing, and fires are mostly smoke with low heat.

Color Setting. When yellowing is complete and the entire leaf lamina is a solid yellow color with little or no brown color,

temperatures are increased with additional fires to set leaf color. Ventilators are usually closed, and temperatures should be kept between 100°F and 115°F. These conditions should be maintained until the leaf shows a solid brown color. Depending on tightness of the barn and weather conditions, color setting may be done with one firing or may take two successive firings over a seven- to 14-day period. Ventilators should be opened completely between firings to allow the tobacco to obtain some order before refiring. When the tobacco has a clear, solid brown face and the stems are dried and browned one-half to two-thirds up the leaf, it is time to complete drying.

Drying. Tobacco is brought in order, ventilators opened, and heat increased until the midribs are completely dried down and darkened. Heat during the drying phase should not exceed 130°F. When drying is complete, very little or no green pigment should be left in the stalks; tobacco should shatter when touched, and no puffiness or "fat stems" should be present in the leaf midrib near the stalk. Puffy stems that remain after the drying phase will not easily be dried down during the finishing phase.

Finishing. After the midribs and stalks are dried and darkened, temperatures are reduced to no more than 120°F, and smoke volume is maximized to add "finish" to the leaf surface. The finishing phase usually requires one to two slow firings over a 10- to 14-day period but may vary depending on the amount of finish desired by the buyer. Tobacco takes finish much better when in order, so ventilators should be opened for several nights prior to finishing to allow moisture to enter the barn. Finishing fires should contain minimal slabs and heavy sawdust to maximize smoke with little or no ventilation. The sawdust, barn floor, and walls may be dampened to produce a moist smoke that will help keep the tobacco in order longer to increase finish.

Firing Materials and Methods

Hardwood slabs and sawdust are the traditional firing materials used for dark fire-cured tobacco. Seasoned hardwood materials are preferable, since they tend to burn more slowly and evenly than softer types of wood. Evergreen wood species should be avoided, as they contain resins that can impart off-flavor and aroma to the cured tobacco. Materials, such as sulfur or salt, should not be used in the yellowing or drying phases, and other materials, such as molasses or brown sugar, should not be used during the finishing phase to increase finish in the cured leaf. Where these materials are used, the result may be tobacco that is excessively sticky and difficult to handle or not usable by the industry because of off-flavor.

With traditional fire-curing, initial fires during yellowing and color-setting usually consist of slabs being placed in narrow rows on the floor of the barn and covered completely with sawdust, except for a small opening exposing slabs on alternating ends of each row where fires are started. Slabs should be overlapped so that fires will burn continuously to the end of each row. Later firings during the drying phase require increased heat, and slabs may be stacked higher and in wider rows or beds or placed solid throughout the floor of the barn with sawdust covering the slabs.

Fires may be started on one or both ends of rows. Fires started on one end of a row will burn slower, whereas fires started on both ends will burn faster and hotter. Finishing fires usually have minimal slabs placed either in rows or solid with increased amounts of sawdust to produce maximum smoke volume. Hardwood chips may also be used in combination with sawdust during later firings to help fires burn more slowly with increased smoke volume (Bailey 2006b).

Good quality sawdust is the most important material used in fire curing. The sawdust over the slabs acts as a damper to allow for a smoldering fire with little or no open flame. Excessive open flames are more of a fire hazard to the barn, and result in excessive temperatures and increased levels of NOx gases, which may contribute to increased TSNA formation (see TSNAs in Burley and Dark Tobacco, page 65).

The dark-fired tobacco industry is dependent on the sawmill industry to provide an adequate supply of slabs and sawdust for fire-curing. This dependence has resulted in increased prices for these firing materials in years when the sawmill industry is slow, causing shortages of these materials, particularly sawdust. The coarse sawdust from circular sawmilling is much preferred for use in fire-curing. Although there have been times when fine sawdust from band saw mills seemed more plentiful, the coarser circular sawdust is always preferred. Band sawdust is much finer and may also have much less uniform particle size than the coarser circular sawdust. The finer band sawdust also has somewhat different burning qualities than the coarser circular sawdust. It has been observed that the finer band sawdust may tend to cake more, allowing the fire to tunnel under the sawdust, preventing some of the dampening effect of the sawdust on the slabs and increasing temperature and open flame in fire-curing barns. It has also been observed that the finer band sawdust may tend to allow burning on top of the sawdust. The finer band sawdust can also be more difficult to wet prior to use in fire-curing barns, and when wetted over the top of rows in the barn, only contributes to more caking and more tunneling of the fire underneath the sawdust. Wetting piles of band sawdust for 1 to 2 days prior to loading in the barn is recommended if dry band sawdust must be used. Growers using the finer band sawdust should use extra caution when firing and those supplying sawdust to growers should be aware that circular sawdust is much preferred.

In the past few years, several buyers of dark-fired tobacco have asked growers not to fire the tobacco as many times as they had been in the past. This preference for less firing is likely an effort to reduce the amount of benzo[a]pyrene (BaP) present in the cured leaf. BaP is a carcinogen that is particularly high in dark fire-cured tobacco due to the curing process. Research has shown that, in general, more firing results in increased BaP (see TSNAs in Burley and Dark Tobacco, page 65). To limit BaP formation, tobacco should be fired only until midribs are sufficiently dry. Contrary to traditional firing methods, growers should now avoid additional firings just to add more finish to the leaf.

Double-Crop Curing Dark-Fired Tobacco

Double-crop curing refers to curing two crops of dark-fired tobacco in the same barn and season. Double-crop curing requires additional planning and management for both the field and curing barn compared to conventional single crop curing. It generally takes about six weeks to fire-cure a crop of dark tobacco by conventional means. This time frame can still be

applied to the later second cures in double-crop curing, but the first cure needs to be fired more aggressively, so that it can be taken down in no more than four to five weeks to allow timely harvest of the second cure. The two cures need to be harvested about five weeks apart, so they should also be transplanted about five weeks apart. First cures should be transplanted as soon as possible, ideally May 1-15. Second cures should be transplanted June 5-20. If this time frame is followed, first cures will be ready for harvest in mid- to late August, and second cures can be harvested in late September to early October.

The most critical part of double-crop curing is the aggressive firing of the first cure. Whereas the first fires for single crop cures are not usually started until around seven days after housing, first cures for double cropping usually need to be fired sooner to stay on schedule. Fires for single-crop curing can be allowed to go out for a few days between later fires after color is set in the lamina, possibly allowing the tobacco to come in order a bit so it will take finish better. Double-crop first cures, however, need to be fired almost continuously, with little or no delay between firing to stay on the four- to five-week schedule. Artificial moisture will almost certainly have to be used to takedown first cures in a timely manner. This moisture can be added with overhead misting systems built into the top of the barn so water can be applied over the top of the tobacco or by applying steam up into the tobacco from the barn floor. Sidewall misting systems can also be installed to help in wetting the floor of the barn for ordering tobacco, and can also be used to cool fires that become too hot during curing. Most dark-fired crops will need two applications of misting or steaming to stabilize moisture in the leaf to allow takedown. Caution should be used with any artificial moisture source to prevent tobacco from getting too high in order. Steam or mist only enough to allow the tobacco to be taken down. Additional steaming or misting to allow stripping can be done later on the wagon if needed (Bailey, 2007).

As stated previously, traditional fire-curing methods involve laying (3- to 4-foot wide) rows of hardwood slabs covered with sawdust perpendicular to the length of the barn. One end of each row is lit for a slower, lower-heat fire during early stages of curing, while both ends of rows are lit for higher heat for drying. This process is repeated two times or more, with each firing event lasting between 5 and 10 days.

Recently, larger growers have begun to use higher volumes of wood and sawdust during curing to allow the process to be completed in only two firings. Slabs covered with sawdust are laid in beds 5- to 6-foot wide or more that run parallel with the length of the barn. Heavier volumes of sawdust are placed over the slabs than in traditional curing methods so that fires last longer. Several fires are lit in each bed and may burn for up to 14 days. Research has shown a 39% savings in wood curing materials used with this high-volume firing method compared to traditional fire-curing in a first cure (early crop) (Table 1). Second (late-season) curing typically requires more wood consumption in order to maintain desired barn temperatures as outside temperatures are colder during late-season curing. However, savings in wood consumed was still 16% with high-volume fire curing compared to traditional fire curing of a second (late) crop.

Using Fans in Conventional Air-Curing Barns

High-volume ventilation fans can be used in conventional barns to aid air circulation and improve curing. When using fans to aid curing, make the air pass through the tobacco rather than just circulate around the driveway or gable space. You also need to move enough air to justify your effort in using the fans. Most fans in the gable end of conventional barns are too small to do much more than short-circuit air through nearby wall and eave cracks. Fans at ground level in driveways or doorways need to have means (boards, etc.) to direct and/or deflect air up through the tobacco for more effective results.

The most efficient and effective method of using fans in conventional air-curing barns with numerous openings around the eave, walls, and doors is to place good quality, belt-driven ventilation fans horizontally in the center, bottom rail of every other bent. This placement pulls any humid, stagnant air through the mass of tobacco from above and around the fan and blows it directly toward the ground. Thus, air is moved through the central core of the tobacco where moisture problems generally first occur. To prevent damage by the fan, sticks of tobacco are omitted directly above the fan and plants are moved sufficiently away from the sides. Leave the side ventilators or other doors open to allow the ground-level, moist air to migrate out of the barn and fresh, drier air to come in around the eave, through the sidewall vents, and through the tobacco.

For beneficial curing results, fan capacity should be 12,000 to 18,000 cubic feet/minute of 0.1-inch static pressure-rated airflow for every two bents of 32- to 40-feet-wide barn. This means good quality fans of 42 or 48-inch diameter; one-half, or three-fourths hp should be suitable for the above circulation method in conventional barns, depending on barn size, amount of tobacco, and the effectiveness of air movement you desire. Details on fan selection and location are given in a separate publication (Duncan, 1992).

Operate the fans 24 hours a day during rainy or humid weather and/or daily during the first two or three weeks of curing when the tobacco is still green or yellow and contains

Table 1. Comparison of wood consumption in traditional and high-volume fire-curing methods, University of Tennessee Highland Rim Research & Education Center, Springfield TN, 2015.

	Fire-curing Method	
	Traditional Fire-curing (rows)	**High-volume Fire-curing (beds)**
First (Early) Cure:		
Number of firings	3	2
Total Weight of slabs used per cure	4495 lb	3226 lb
Total weight of sawdust used per cure	5226 lb	2686 lb
Total cured weight of tobacco	1500 lb	1500 lb
Cured tobacco:Wood ratio	1:6.5	1:4
Wood savings		39%
Second (Late) Cure:		
Number of firings	6	2
Total Weight of slabs used per cure	7613 lb	7000 lb
Total weight of sawdust used per cure	8058 lb	6162 lb
Total cured weight of tobacco	1500 lb	1500 lb
Cured tobacco:Wood ratio	1:10.4	1:8.8
Wood savings		16%

turgid stalks and stems. After about three weeks, the fans may be operated only during the day to dry the tobacco as needed and turned off at night to avoid bringing in moist air. Time clocks can be installed to automatically power the fans on and off each day.

Don't operate the fans during cool, dry weather (below 50 to 60°F and below 60 to 65% relative humidity) when the tobacco still has green or yellow color in the leaves, as over-drying and off-colors can result.

When planning to use the electrically powered fans in conventional barns, carefully check the existing electric wiring and service entrance components. Many barns have been wired for only driveway or stripping-room lights and do not have enough capacity to operate fan motors. Damaged and burned-out wiring or motors can quickly result from insufficient electrical service capacity. Have a local electrician or utility company representative help you check your electrical circuits.

Tobacco Stripping Rooms

A good stripping room is very helpful for the stripping and market preparation tasks for most producers. Some producers strip early in the fall in the barn driveways, using wagons for the stripping work area. Others can get by with temporarily enclosing a portion of the barn with plastic, tarps, etc., using an improvised or fold-up workbench and portable vented heater or stove, or they can haul the unstripped tobacco to a more suitable location. The advent of the big baler for burley baling requires greater space for the baler, a supply of unstripped tobacco, and the accumulation of stripped tobacco. As a baler is being filled with 550 to 750 pounds of one tobacco grade, the additional leaf grades stripped from the plants must be stored somewhere. Such storage can be avoided only by operating multiple balers at a greater cost.

Heated workshops or garages can serve as temporary stripping areas. Likewise, any permanent stripping room can also serve as a workshop or storage area the rest of the year, if suitably arranged and conveniently located. Features to be considered for a stripping facility include:

- Workbench of proper width and height (see website below) or appropriate mechanical stripping aid
- Overhead lighting with shatterproof shields
- Adequate space for workers bringing in stalk tobacco, baling equipment, and removing the bare stalks
- Doorways large enough to accommodate the tobacco handling equipment and personnel
- Heating equipment (with proper exhaust venting) for warmth in cold weather
- Electricity for the lights and power equipment needs

Blueprints available from the BAE website show typical construction of traditional stripping rooms https://www.uky.edu/bae/content/tobacco-plans#room. Some possible layouts of larger stripping rooms for the big baler operation are also shown on the site https://www.uky.edu/bae/sites/www.uky.edu.bae/files/StrRmLys.pdf). Benches should be 32 to 36 inches high and 48 to 60 inches wide for one side stripping or double width for workers on both sides. The top surface of the benches should be slatted wood or heavy wire mesh with half-inch crack openings that allow fine particles of trash and debris to fall through. Dual-chain stick conveyors (stripping chains) that move sticks past workers for hands-free stripping with no bench have become very popular among dark tobacco growers. However, these stick conveyors require additional space that needs to be considered in stripping room design.

Overhead lights should be multiple-tube fluorescent fixtures with a reflector shield, protective mesh grid, and equal numbers of cool white and daylight type tubes per fixture. These tubes provide a good, economical light source to see the tobacco color and grade qualities while stripping. Each tube should also have a shatter-guard cover to protect the tobacco from glass contamination should a tube shatter. Special lights with a more balanced daylight spectrum and quality of light are other options.

Another consideration for stripping room design is efficient removal of tobacco stalks from the stripping room after tobacco leaves are removed. Moving bulky tobacco stalks out of the stripping room to a wagon or spreader, and then spreading the stalks on a field takes additional labor and time. Some large tobacco operations are beginning to experiment with stalk choppers set up just outside the stripping room where stalks can be placed in the chopper through an opening in the wall. A demonstration of this can be found at: https://www.youtube.com/watch?v=FOLj9JEBiUs

Tobacco stripping rooms should be kept free of trash and other foreign matter that could contaminate the tobacco. Tobacco buyers have no tolerance for non-tobacco-related material (NTRM). NTRM contamination of tobacco is most likely to occur during stripping, so cleanliness of stripping rooms is very important. Any NTRM should be removed from the stripping room before stripping begins, and workers should take breaks and deposit trash in an area separate from the stripping room. Care should be taken to avoid contamination from petroleum products, or chemicals stored in shop areas that double as stripping rooms and market preparation areas.

References

Bailey, A. 2006a. Harvesting, Curing, and Preparing Dark Air-Cured Tobacco for Market. AGR-153. Coop. Ext. Service, University of Kentucky, Lexington.

Bailey, A. 2006b. Harvesting, Curing, and Preparing Dark Fire-Cured Tobacco for Market. AGR-152. Coop. Ext. Service, University of Kentucky, Lexington.

Bailey, A. 2007. Double Crop Curing Dark Tobacco. AGR-196. Coop. Ext. Service, University of Kentucky, Lexington.

Duncan, G.A. 1992. Using Fans in Conventional Burley Barns. AEN-69. Coop. Ext. Service, University of Kentucky, Lexington.

Jeffrey, R.N. 1940. The Effect of Temperature and Relative Humidity During and After Curing upon the Quality of White Burley Tobacco. Bulletin No. 407, Kentucky Agricultural Experiment Station, University of Kentucky, Lexington.

Walton, L.R., and W.H. Henson Jr. 1971. Effect of environment during curing on the quality of burley tobacco. I. Effect of low humidity curing on support price. Tobacco Science 15:54-57.

Walton, L.R., W.H. Henson Jr., and J.M. Bunn. 1973. Effect of environment during curing on the quality of burley tobacco. II. Effect of high humidity curing on support price. Tobacco Science 17:25-27.

Stripping and Preparation of Tobacco for Market

Andy Bailey and Bob Pearce

The market preparation phase of tobacco production involves the removal of cured tobacco from the curing facility, temporary bulking, removal of leaves from the stalk (stripping), grading by physical characteristics, and packaging for market.

Takedown and Bulking

Tobacco should not be removed from the curing facility until all the stems (midribs) of the leaves have dried to a firm condition (not "fat" or "mushy"). Takedown and bulking are the processes of removing cured tobacco from the curing structure and consolidating for access by workers or transport to a remote stripping location. Tobacco that must be transported to the stripping location can be consolidated onto a scaffold wagon or bulked onto a flatbed wagon, truck or trailer. Tobacco should be bulked on a clean, dry surface such as wooden boards, pallets, a wagon bed, or similar surface. A plastic sheet can be used as a protective barrier onto which the tobacco can be bulked, but be aware that a layer of moisture can condense on plastic under certain atmospheric conditions. Periodically check tobacco in contact with plastic to detect any moisture problems.

Tobacco must be in a pliable condition for handling and bulking, which is often referred to as being in "order" or "case" and occurs with exposure to an environment of 70% or higher relative humidity for several hours (four to 12 hours, depending on the temperature). Producers typically wait for natural weather conditions of good humidity and temperatures above 35°F for conditioning the tobacco for handling. In extreme dry periods, steamers or overhead misting systems (in dark-fired barns) can be used in barns that are somewhat airtight for artificially conditioning tobacco for handling.

Tobacco in equilibrium with air below approximately 60 to 65% relative humidity will be so dry that leaves will likely shatter when handled, thus losing quality and weight. Conversely, exposure to a continuous relative humidity of greater than 85% will cause the tobacco to become too moist and subject to deterioration and damage when bulked or baled. High-moisture tobacco will "heat up" in the bulk after a day or so in warmer weather (above 50 to 55°F daily average), causing undesirable mold development, a bad smell, potential discoloration, and, in a worst-case scenario, rot.

No inexpensive tool yet exists for growers to quickly and accurately determine the moisture content of cured tobacco. Such a tool could significantly benefit growers in managing their stripping and baling operations to minimize problems related to moisture content. Currently, grower experience is the best tool for determining moisture content of cured tobacco. A leaf in proper order will yield without crumbing when squeezed in the hand but should spring back slightly after being released. The base of the stem should remain brittle and snap or break when doubled over. Indications that leaf moisture may be too high for safe baling are when the leaf remains compressed even when released, and when the stem is completely pliable even when doubled over.

Several different methods are used for bulking tobacco. Tobacco can be bulked either with sticks still inserted or removed. Bulking with the sticks inserted is often a method used early in the fall to provide better air and moisture diffusion from the bulk when the stalks are still "green" and moisture laden. Stick bulking can also make it easier to handle the tobacco at the stripping location. Removing the sticks when bulking can be done when the stalks are dry enough (general brown color) that the moisture will not cause "heating" or other problems when the bulked stalks are tightly packed for several days of warm weather (above 45 to 50°F daily average) before stripping. If the stalks are still green and moist when bulked, strip within two to three days. Put wooden sticks between bunches of stalks to permit better ventilation and moisture diffusion when bulking for an extended period.

In any bulking method, place your hand deep into the bulk daily to determine that the tobacco is still cool and not beginning to heat up. If warmth is detected, then prepare to strip the bulk promptly, open the bulk, or move the tobacco around to air out. If heating occurs, moisture level should be reduced before baling.

If dust or other contaminants are not prevalent, the bulk of tobacco can be left uncovered in mild fall weather to allow moisture diffusion. Later in the cooler and drier fall or winter weather, a tarp or plastic cover can be put loosely over the bulk to protect it from excessive drying and prevent dust accumulation or other contamination.

Tobacco can also be taken down and put on scaffold wagons until stripping if wagons and storage space are available. In warmer fall weather, tobacco taken down onto scaffold wagons will be less likely to heat and does not have to be stripped as quickly as it would if it were bulked. The entire scaffold wagon can be loosely covered with plastic to retain moisture until the tobacco can be stripped.

It is very useful to have an "ordering/casing room" with heat and humidifiers available and adequate sealing to control humidity. With this setup, tobacco bulked down on wagons or pallets or hung on scaffold wagons can be brought into proper order overnight for stripping the next day. Having this capability can help minimize the downtime often experienced during dry periods in the fall when the natural relative humidity is too low to bring tobacco into proper order. The ordering room should be large enough to hold at least one-day's supply of tobacco for stripping.

Stripping Burley

Stripping is the process of removing and grouping leaves by stalk position and physical characteristics to meet marketing requirements. A full-leafed mature burley plant can have 20 to 24 leaves. Producers who strip their tobacco into four grades typically grade into the four stalk-positions—flyings (also referred to as trash), lugs (cutters), leaf, and tips—that are true to former Federal Grade standards. Properly done, this grouping will be acceptable to all buyers, but some buyers may not care about a separate flyings grade or a true tip grade and will not pay a premium for them. In this case, it could be more profitable for the producer to strip the crop into three grades.

Company specifications for grading tobacco can vary significantly; therefore, growers should review their contracts and talk with company representatives regarding their specific requirements. Some buying companies require only three grades. Often weather, soil, and curing variations are such that only three distinct grades of leaf characteristics may exist on most plants. Over-mature harvest and/or loss of lower leaves during harvest may reduce the lower stalk position (flyings or trash) group. Several of the newer burley varieties maintain such sound lower leaves that a true flyings grade may not be produced. Growing conditions, agronomic practices, and variety may also limit the number of true tips that can be produced. Stripping of these plants into three grades might be accomplished without significant loss in value if the marketing process permits. Past studies have shown that the labor cost to remove a fourth grade of limited quantity and value is not always economically feasible (Bridges et al., 2006).

The traditional stripping methods of growers who put tobacco into three grades often result in mixed grades from the buying company standpoint. As the companies make their blends, they look for specific characteristics that differ from grade to grade. Tobacco companies can use a small percentage of mixed-grade tobacco, but the handling characteristics of the basic stalk positions differ substantially during processing. Even companies that only require three grades do not want a mixed grade of lighter lower stalk tobacco (cutter) with heavier-bodied upper stalk tobacco (leaf). Tobacco stripped into three grades is typically grouped into flyings, lugs, and a leaf/tip grade. With three-grade tobacco, producers tend to strip too high on the first grade (lower stalk) for a true flying grade but not high enough to get a good separation between lower stalk and upper stalk tobacco in the second grade. Generally, they put too many leaves into the third grade for a true tips grade. Thus, three-grade tobacco often will have a mixture of flyings and lugs in the first grade, a mixture of lugs and leaf in the second grade, and may have a mixture of leaf and tips in the third grade. Depending on the buying company, the first grade and third grade in this type of stripping may be acceptable, since the first grade is clearly all light-bodied lower stalk tobacco and the third grade is all heavier bodied upper stalk tobacco. However, the mixed middle grade will be a problem for all buyers. This may reduce market quality grades from 1's or 2's to 3's, and the mixed middle grade may be classed as cutter instead of leaf. This reduction in quality grade has happened quite a bit with some of the lighter-colored, thin-bodied crops produced in dry years. If the mixed nature of the middle grade leads to a C3 grade, this can be quite costly for the producer compared to a more careful separation of lower and upper stalk tobacco. Generally, companies that want tobacco stripped in three grades want all flyings and cutters in the first grade, lighter bodied leaf in the second grade, and the shorter, darker heavier bodied leaf and tips in the third grade.

Some tobacco company contracts that require four grades use a very strict definition of tips and/or flyings, which means fewer leaves in these grades compared to the way tobacco farmers have normally stripped. One such crop throw would typically put only one to three leaves into flyings (trash), five to seven leaves as lugs (cutters), half of the stalk (10 to 12 leaves) as leaf tobacco, and the remaining two to four leaves as tips. Again, growers should review their contracts and check with company representatives for a clear understanding of how the buyer wants the tobacco separated into grades.

The predominant means of leaf removal is still by hand methods, with the relay method generally being the most used and still predominant on small and medium sized farms. The relay method uses workers along a bench 32 to 34 inches high or wagon bed, with a source (pile) of cured plants at one end. The first worker pulls the lowest grade and lays the stalk on a pile for the second worker to remove the next grade and so on until all leaf grades have been removed. The stripped leaves are generally placed on the table or in a receptacle (tray, box, etc.) adjacent to the worker so another worker can conveniently gather the leaves for baling and carry out other support tasks such as removal of stalks and bringing in more plants. For handling into the now-predominant big bales, large plastic hampers, heavy-duty cardboard boxes, vegetable bins, or burlap sheets are being used to accumulate leaves of each grade before "big baling."

Another manual method of hand stripping involves each worker removing all grades from a plant, placing the leaves in separate receptacles, and placing the stalks in a "stalk rack." Other workers collect and carry the leaves and stalks to appropriate boxes, sheets, balers, or wagons.

Bare stalks accumulated at the end of stripping are periodically carried to a separate wagon, manure spreader, or similar vehicle for later transport to a field for spreading and disposal. Stalk choppers and conveyors for removing the stalks have been adapted by some producers (see https://www.youtube.com/watch?v=FOLj9JEBiUs for more information on tobacco stalk choppers).).

There have been some fully mechanical stripping systems developed over the years. A mechanical leaf-removing stripping machine developed by Carolina Tobacco Services[1] that was introduced at tobacco field days and trade shows in 2006-2007 initially received considerable interest from the tobacco industry. The CTS stripping machine uses "sticker" type chains to hold the tip end of plants hanging vertically downward, conveying them past angled wiper bars that strip off leaves as the plants move through a length of 14 to 16 feet. Different leaf grades fall into boxes below the plants along that length. Tips must be stripped by hand before loading the plants into the machine. Evaluations conducted both by the University of Kentucky and the University of Tennessee have shown that this machine can significantly improve labor efficiency over typical manual stripping. In one study, a crew of seven workers could strip around 70 pounds per worker-hr., or about 35 worker-hr./A for a 2,500-pound per acre crop (compared to 50 to 75 worker-hr./A for conventional stripping) (Wilhoit and Duncan, 2013). This technology was not widely adopted by growers.

Another automated stripping concept that was developed in the Department of Biosystems and Agricultural Engineering at the University of Kentucky is a high-capacity mechanical stripping system that segments the tobacco plant into sections of stalk with leaf attached (for each grade), and then separates the leaf pieces from the stalk pieces (Day et al., 2012; also see https://www.youtube.com/watch?v=NFhkJV21U58). Given the expected costs and complexity of either of these machines, these concepts would likely involve growers bringing bulked tobacco to a central location for custom stripping. The stalk and leaf segmenting system was operated on a limited commercial

basis during the 2018 and 2019 growing seasons. A total of 350,000 pounds was stripped and delivered to two companies that agreed to accept leaf from the system on a trial basis in 2019. Quality feedback was favorable from both companies. If interested in automated stripping, check with your company grower representative to see if the system is available in your area and accepted by the company.

With the predominant use of big baling and the non-oriented leaf packaging that it allows (see later section "Burley Baling"), many growers have found that different mechanical stripping aids help improve the efficiency of their stripping operations. Stripping aids such as the stripping wheel and various types of straight-line stick conveyors that move the stalks past the workers allow them to use both hands for faster removal of leaves from the stalk. These aids seem to work well with the larger scale stripping operations often used to accommodate single or multiple big balers. Chain conveyors which move tobacco still on sticks past workers have particularly gained popularity on larger burley and dark tobacco farms. Studies done in the 1990s when stripping wheels were introduced showed mixed results in terms of how much these and other stripping aids improved efficiency. Efficiency gains ranged from a small percentage up to 30 to 40%. However, these studies were done with small bales, so that the stripped tobacco had to be oriented in small batches in bale boxes. With large bales and non-oriented/tangled leaves, producers seem to find the various stripping aids more advantageous. Some producers are incorporating flat belt conveyors into their stripping operations to move leaves to the baler.

Other growers are finding different setups for incorporating big balers into their stripping operations are more useful than stripping aids. Studies at the University of Tennessee showed that being well organized in carrying out various auxiliary tasks was more important to labor efficiency. Keys to increased productivity with stripping aids and other systems are to make sure that each worker performs efficiently as part of the team, tasks are reasonably balanced or staged in terms of time required per worker-task, and the flow of tobacco and stalks in and out is smooth and efficient, with minimum distance required for human handling. Examples of stripping room layouts with various options for handling loose leaf tobacco prior to baling can be found at: https://www.uky.edu/bae/sites/www.uky.edu.bae/files/StrRmLys.pdf.

Burley Baling

The small conventional bale of oriented leaves with air cylinder compression in wooden boxes (an industry standard since the 1980s) has been replaced by tangled-leaf big tobacco bales. Studies done at the University of Kentucky and the University of Tennessee have found improvements in labor efficiency ranging from 15 to 25% with the use of big bale packaging, and many growers feel that they have achieved similar savings. Most big balers use hydraulic cylinder compression to form the bales in the nominal size, 42 inches wide x 40 inches tall x 42 inches long, chambers. Some big baler designs use air cylinders, but it takes a very large air cylinder to compress the tobacco to densities even approaching that of tobacco compressed by hydraulic cylinders and very large air compressors to supply such cylinders. Increasing density requirements will make it more difficult to use air cylinders.

Hydraulically operated big balers can be powered by a 230-volt electric motor or tractor hydraulic connections. The tractor-powered baler costs less and permits movement to barns and stripping room locations where 230-volt power may not be available. The big balers have optional load cells with an electronic display to show the weight of leaves in the chamber, thus permitting desired bale weights. Big balers can receive non-oriented, tangled leaves, which presents new options and opportunities for mechanically removing and handling leaves from stalks when stripping, as discussed above.

The buying industry initially required big bales in the 500 to 600-pound range, but weight specifications have been increasing since the big balers were introduced in 2005. Depending on the buyer and tobacco grade, some tobacco is now packaged in bales ranging in weight from 700 to 750 pounds. Moisture content specifications have also been decreasing during that same period. Some companies now want moisture levels of 20% or less, which can be very difficult to achieve with heavier bodied grades in years with high humidity at stripping time. The combination of higher tobacco density and lower moisture content specifications in the bale contributes to moisture content difficulties with big bales. Because of the larger mass of leaves and longer moisture diffusion flow path of the big bale from the inside to the outside, the moisture content of big bales cannot equalize with the surrounding environment as quickly as small, oriented leaf bales.

At the buying stations, the moisture content of the big bales that are received are assessed with a microwave moisture analyzer instrument known as the "Malcam" (Malcam LTD., Tel Aviv, Israel). These instruments are calibrated to determine an average moisture content value for a bale based on microwave signals transmitted through the bale. The technology allows bale density to be considered. At the farm level, there are moisture probes similar to hay testing probes, but with different calibrations, designed for measuring the moisture content in bales of burley tobacco. Two such probes are the Tobacco Chek moisture meter (Dagmar Enterprises LLC, Leawood, KS) and the Delmhorst F-2000T (Delmhorst Instrument Company, Towaco, NJ). These testers measure moisture in only a small area of the bale near the tip of the probe, so a bale must be tested in at least 3 to 4 locations to determine the average moisture for the bale. The probes seem to work best in well-cured, dry tobacco, but often provide erratic readings in high moisture zones or where fat stems are present. In evaluations conducted by the University of Kentucky with a cooperating grower on approximately 100 big bales, the average of three probe readings per bale were generally like the Malcam moisture content readings obtained for the same bales at the buying station. However, readings for individual bales often differed significantly. Growers should not rely on the moisture content levels determined by probes as a primary means to determine the marketability of bales of tobacco.

Growers have experimented with various ways to remove moisture from big bales with moisture content above acceptable levels. It takes a lot of work to open and flake apart big bales for drying. Trials performed at the University of Kentucky have shown it was possible to get enough air movement through 600-pound bales to reduce the moisture content 1 to 2% over a period of several hours, depending on the ambient conditions.

Such drying rates may be far too slow to benefit large stripping operations, however, and even those drying rates may not be a realistic expectation with the increased density of 700+ pound bales.

Stripping Dark Tobacco

A fully mature dark tobacco plant will have 16 to 18 marketable leaves. Dark tobacco (fire-cured and air-cured) has traditionally been sorted into three grades at stripping. These grades include lugs (three to six leaves showing some ground injury from the lower portion of the stalk), seconds (four to six leaves from the middle portion of the stalk), and leaf (four to six leaves from the upper stalk). In addition, separate grades should be kept for "trash" and "green." The trash grade is partial leaves from the bottom of the stalk or whole leaves that show excessive ground injury, and the green grade is leaves from anywhere on the plant that show an excessive green cast appearance or that have dark green areas resulting from sunburn or other weather-related damage in the field. Most marketing contracts will not support trash and green grades. Currently, major buying companies have begun requiring only two grades (lug and leaf), with the seconds grade split between the lug and leaf grades. Most contracts will require a crop throw of 10 to 25% lug and the remainder leaf. At least one marketing contract even combines the lug and leaf into one grade. Target moisture levels at delivery are generally no more than 25% for dark fire-cured and 22% for dark air-cured. Refer to marketing contracts for specific stripping, grading, and marketing specifications.

Marketing Packages for Dark Tobacco

Baskets

The basic and traditional unit of many dark tobacco marketing packages has been what is known as a "flake." Flaking dark tobacco involves manually compressing leaves during stripping into a small flake box (typical inside dimensions 4 inches wide x 19 inches tall x 26 inches long) that stands vertically so that a 4-inch layer or "flake" of tobacco is formed with the leaf butts aligned. Flakes should generally not be more than 4 inches thick and 20 inches in width. Flaking produces compressed layers of tobacco that can be arranged in alternating directions to build the more traditional basket-type marketing packages. "Baskets" or "heads" are generally wooden lids from hogshead storage containers and are usually supplied by the buying company. The flakes of tobacco are stacked on them neatly. If space constraints in the stripping area don't allow baskets to be assembled immediately, flaked dark tobacco may be compressed into small bales (typically 18 inches wide x 12 inches tall x 36 - 44 inches long, depending on the length of the tobacco) for storage until basket-type packages can be made later or at another location. Final weight of basket marketing packages is usually targeted at 850 pounds and should not exceed 900 pounds. Basket-type marketing packages have been the most commonly used marketing package for dark tobacco in past years, but newer more efficient marketing packages for dark tobacco have been recently introduced by some companies.

Boxes and Large Bales

Some dark tobacco contracts allow delivery in C-48 cardboard boxes supplied by the buying company. Dimensions of C-48 boxes are approximately 28 inches wide x 29 inches tall x 40 inches long. Boxes are assembled, uniformly filled with oriented tobacco, and held together with two cotton strings. Use of these boxes generally eliminates the use of small bales for storage until the tobacco can be basketed and, although the tobacco is still somewhat oriented within the box, does not require flaking. Flaked or oriented non-flaked tobacco can be placed directly into boxes at the time of stripping, allowing considerable time savings compared to preparing baskets. Target weight for C-48 boxes of tobacco is approximately 250 pounds. Recently, at least one major dark tobacco buyer has allowed dark tobacco (air-cured and fire-cured) to be baled in large, tangled leaf bales like those used for burley. Consolidation of grades and use of large, tangled leaf bales has resulted in major increases in efficiency during stripping and market preparation of dark tobacco.

Hand-Tied Wrapper Leaf

Dark wrapper leaf is ultra-high-quality dark tobacco that is broad in width, uniform in color, has small secondary veins, and almost no holes or other flaws. Cigar wrapper dark leaf is from the leaf position only and usually makes up no more than 30 to 40% of the total number of the leaves on the stalk. Dark tobacco that is sold as wrapper leaf is still tied in hands and arranged on baskets for delivery. Hands should be neatly tied with 10 to 15 leaves plus one tie leaf. They are usually arranged in a circular pattern on a basket for delivery.

Non-Tobacco Related Materials

As mentioned in the previous chapter, the tobacco industry has no tolerance for non-tobacco related materials (NTRM) or other contamination in tobacco marketing packages. NTRM may be more likely in large bales, requiring more prevention and monitoring. Stripping areas must be kept clean, orderly, and free of any NTRM. Woven synthetic tarps that may become frayed can be a source of NTRM contamination and should not be used during handling and storage of stripped tobacco, or for covering tobacco during transport for delivery to the buying station. Trash accumulated from the stripping area, such as drink cups and food wrappers, are a major source of NTRM. Break areas for workers should be separate from areas where tobacco is handled to reduce the chances of NTRM contamination. Tobacco curing, stripping, and storage facilities should also be made bird-proof so that the tobacco does not become contaminated with bird droppings and feathers. Styrofoam has also become a major NTRM problem for the industry, as Styrofoam particles are very difficult to remove from the tobacco during processing. Ensure that Styrofoam does not come in contact with tobacco at any time during curing, stripping, and market preparation. Remember that NTRM is not just synthetic articles such as Styrofoam, plastic, drink cups and food wrappers, but also includes non-marketable plant material such as stalk pieces, suckers, and weeds. Stripping crews should be trained on the importance of NTRM elimination and monitored frequently to ensure that the stripping area and marketing packages are free of NTRM.

References

Bridges, T.C., L.G. Wells, M.A. Peters, and W.O. Peterson 2006. Evaluation of labor requirements and work rates for conventional stripping of burley tobacco. *Tobacco Science* (2003/2004) 46: 28-32.

Day V, G. B., T. D. Smith, and L. G. Wells. High-capacity market preparation for burley tobacco. Presentation and abstract, 45th Tobacco Workers Conference, Williamsburg, VA. January 16-19, 2012.

Swetnam, L.D., G.K. Palmer, and C.L King. 1995. Tobacco Stripping Wheel Construction Guide. University of Kentucky Biosystems and Agricultural Engineering Department publication. Available at https://www.uky.edu/bae/sites/www.uky.edu.bae/files/strwh.pdf.

Wilhoit, J. H., and G. A. Duncan. 2013. Labor productivity and requirements for stripping burley tobacco. *Tobacco Science 50:1-10.*

TSNAs in Burley and Dark Tobacco

Anne Fisher, Lowell Bush, and Andy Bailey

What Are TSNAs?

Nitrosamines are nitrogenous compounds, some of which are carcinogenic. They are found in a wide range of food and cosmetic products, as well as in tobacco. TSNAs, tobacco-specific nitrosamines, are so called because they are formed only from tobacco alkaloids and found only in tobacco leaves and in the particulate phase of tobacco smoke. With the current emphasis on the health risks of tobacco, TSNA reduction has become a major issue for the tobacco industry.

Several TSNAs have been identified, but interest has focused on the four most important: NNK, NNN, NAT, and NAB. Of these, NNN is the most important in burley and dark tobacco.

How Are TSNAs Formed?

Negligible amounts of TSNAs are present in freshly harvested tobacco. They are mainly formed during curing, specifically during the late yellowing to early browning stage. Typically, this occurs over a two-week period between the third and fifth week after harvest, but can be earlier or later depending on curing conditions.

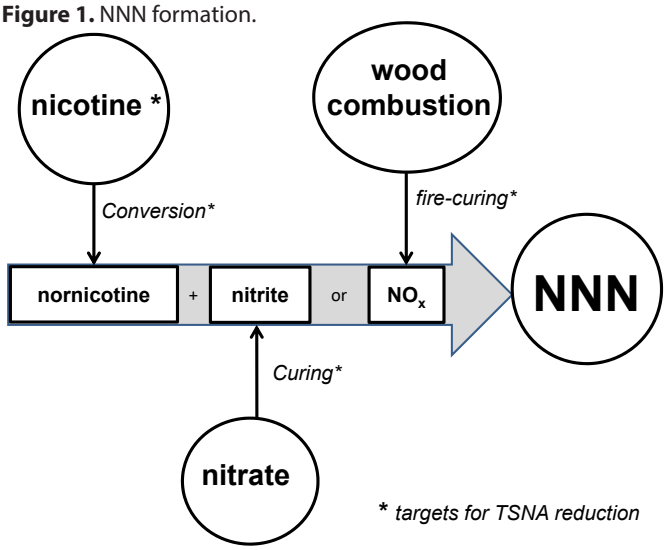
TSNAs are formed by the nitrosation of tobacco alkaloids (addition of a nitrogen and an oxygen atom to the alkaloid molecule). NNN is formed by the nitrosation of the alkaloid nornicotine. The nitrosating agent in air-cured tobacco is usually nitrite, derived from the reduction of leaf nitrate by the action of microbes during curing. In fire-cured tobacco, the nitrosating agents are both nitrite and any of several nitrogen oxides (NOx) formed during the fire-curing process. Both the alkaloid and the nitrosating agent are necessary for the formation of TSNAs. Any practices or conditions that increase the accumulation of either of these groups of compounds would be expected to increase TSNAs.

Factors Affecting TSNA Accumulation

Three main factors affect the amount of TSNA accumulation:

- The amount of specific alkaloid precursor. In the case of burley and dark tobaccos, this is nornicotine, and it is mainly determined by the amount of conversion of nicotine to nornicotine in the seedlot used. Screened or "LC" seed has been selected for low conversion, and we have shown that this results in significantly lower TSNAs.
- The amount of nitrosating agent. Nitrite is the main nitrosating agent for air-cured tobacco and is determined by the microbial populations reducing the leaf nitrate to nitrite. The microbial populations are affected by curing conditions, particularly during the first 35 days of curing. The amount of leaf nitrate, determined by available soil nitrogen, has little direct effect on the amount of leaf nitrite; any effect is probably indirect, through the effect of nitrate on the thickness and drying rate of the leaf. With the levels of nitrate found in the normal production range, the main effect of applied nitrogen fertilizer on TSNAs is through the effect on alkaloid level. During fire-curing, nitrogen oxides (NOx) are the nitrosating agent and are the result of combustion of wood during firing.
- The amount of total alkaloids/nicotine. The relative amount of nornicotine depends on conversion, and the absolute amount depends on the amount of nicotine originally present. The higher the nicotine, the higher the absolute amount of nornicotine (because there is more nicotine available to be converted to nornicotine), and consequently the higher the potential for TSNA accumulation. The amount of total alkaloid is determined partly by environmental conditions, such as rainfall, and partly by agronomic practices, such as fertilization, topping, maturity at harvest, etc.

Figure 1. NNN formation.



If any of these factors (conversion, nitrosating agent, total alkaloids) are reduced, TSNAs are reduced (Figure 1).

Seed Screening

Reducing the amount of nornicotine precursor for NNN is the single most effective step in reducing TSNA accumulation. Figure 2 illustrates the difference in NNN between two varieties, a non-commercial high converter and a screened low converter.

There are very low inherent levels of nornicotine in the green plant; it is mainly formed by the conversion of nicotine to nornicotine during curing. The ability of plants to convert nicotine is under genetic control and most modern varieties have been selected for minimum conversion.

In the US, all the public varieties have been screened; i.e., the foundation seed was selected for low conversion, which is indicated by "LC" (low converter) in the variety name (for example, TN 90LC, KT 204LC). Many other varieties also have this designation. Some varieties do not have the LC designation, but "screened seed" is indicated on the seed pack. All seed of commercially viable varieties has now been screened, and there should be no unscreened seed sold in the domestic seed market.

Prior to universal seed screening, many seedlots had relatively high conversion, and consequently the potential for high TSNA formation. There has been a considerable reduction in TSNAs in recent years as a direct result of seed screening.

What the grower can do

The most important step in TSNA reduction, the use of LC or screened seed, has been taken for U.S. tobacco growers. All seed on the domestic market is now screened, and all contracts with major tobacco companies now require the grower to use LC or screened seed.

Variety

To some extent, there seem to be inherent differences between some burley varieties in their potential to accumulate TSNAs, differences that are not explained by conversion levels. These differences are small, but they do appear to be real. For example, it appears that KT 204LC often has lower TSNA levels than some other varieties (Figure 3). We do not yet understand the mechanism for these varietal differences. Like all factors affecting TSNAs, these differences are not always apparent. They are dependent to a large extent on the environmental growing and curing conditions; differences are more likely to be apparent under conditions conducive to higher TSNA accumulation (Figure 3A). While most varieties accumulate higher levels of TSNAs under curing conditions favorable for TSNA accumulation (NCBH 129LC in Figure 3B), the level of TSNAs in KT 204LC does not seem to increase with more favorable curing conditions (Figure 3B).

To date, no varietal differences in TSNA accumulation have been observed in dark tobacco varieties.

Figure 2. NNN (ppm) for high converter (HC) and low converter (LC) burley varieties over two years. Within each year, bars with different letters are significantly different at the 5% level.

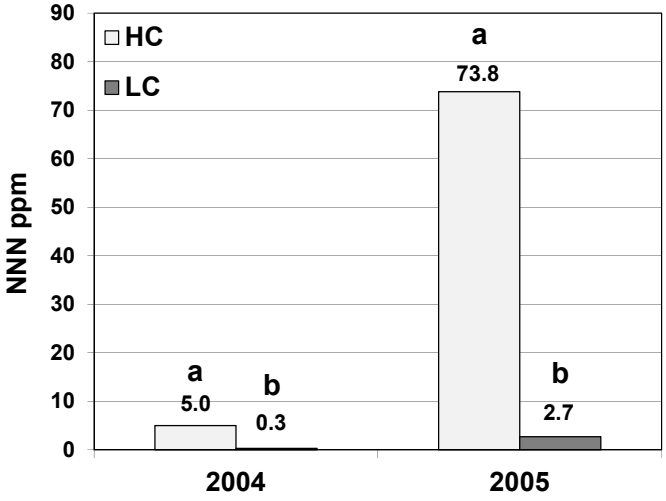
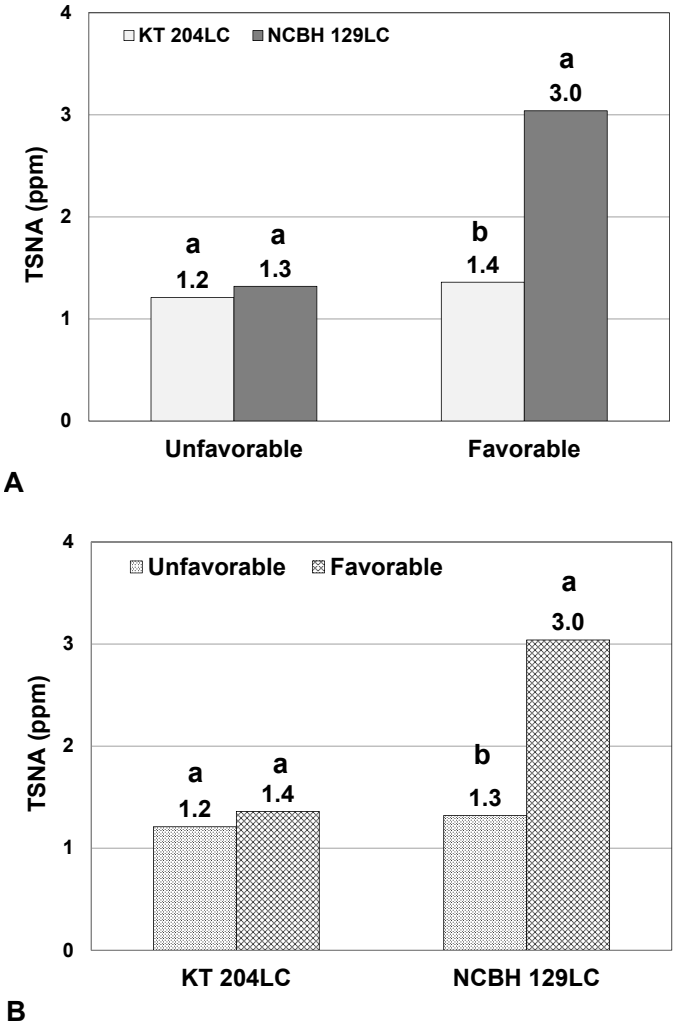


Figure 3. Total TSNAs (ppm) for KT 204LC and NCBH 129LC cured under conditions favorable and unfavorable for TSNA accumulation. **3A.** Varieties within each curing regime. **3B.** Curing regimes within each variety. Within each group, bars with different letters are significantly different at the 5% level.



What the grower can do

Variety choice is a minor consideration in relation to TSNA accumulation.

- Choose the variety most suited to local conditions, paying particular attention to the disease spectrum. If KT 204LC meets the requirements, the choice of this variety may contribute to lowering TSNAs.

Fertilization

Nitrogen fertilization has a considerable impact on TSNA accumulation in the leaf, but the effect is probably indirect; nitrate is probably not directly involved in TSNA synthesis in the leaf. Nitrate affects TSNA levels mainly through its effect on alkaloid levels, and also through the effect on the body and drying rate of the leaf. However, high nitrate in the leaf is undesirable because additional TSNAs may be accumulated during storage and cigarette smoking.

Many studies have found large differences in TSNAs between very high and very low nitrogen rates. However, within the normal production range, the effect was observed to be much smaller and often inconsistent. Growing and curing conditions can play a large role in determining how nitrogen rates affect TSNAs, even when the rates are extreme. Only when many studies were pooled were researchers able to show a clear relationship between the amount of applied nitrogen and TSNA accumulation. Figure 4 shows the strong linear trend for TSNAs to increase with increasing nitrogen. On average, TSNAs will increase 0.05 ppm for every 10-pound per acre increase in applied nitrogen.

The total amount of applied nitrogen is the critical factor, regardless of whether it is all applied as a pretransplant application or is split between pretransplant and sidedressing. Sidedressing does not appear to cause a significant increase in TSNAs, as long as it is applied at the recommended time. Applying sidedress nitrogen later than six weeks after transplanting could increase TSNA levels under some conditions.

There is no clear link between nitrogen source and TSNAs.

Fat stems can increase TSNAs by retaining moisture in the leaf stem. Fat stems can be caused by late uptake of nitrogen (late sidedressing or a dry period followed by rain shortly before harvest).

While the amount of applied nitrogen is important, the most important factor is the amount of available nitrogen, which depends partly on the soil type. We have measured large differences in TSNA accumulation between growing locations, where higher TSNAs were associated with heavier, more fertile soil. It is necessary to exercise particular care when fertilizing these heavier soils.

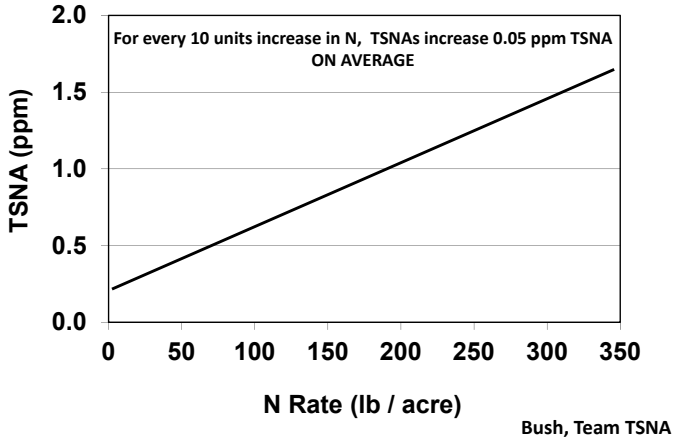
Recent research has shown that spring applications of potassium chloride (muriate of potash, 0-0-60), even at the recommended rate of only 100 lbs 0-0-60 per acre, may result in lower TSNAs in cured leaf.

What the grower can do

Judicious fertilizer application is one of the more feasible steps a grower can take to reduce TSNAs.

- Apply no more nitrogen than is necessary for the crop. Apart from minimizing TSNAs, there are many other good reasons to avoid excessive nitrogen—not the least of which is cost. Excess nitrogen can also cause disease problems and contribute to groundwater pollution, and it does not increase yield.
- If sidedressing, apply nitrogen within four to five weeks after transplanting.
- Use muriate of potash at 100 lbs/acre in spring applications, with the remainder of the potassium recommendation coming from sulfate of potash.
- Exercise particular care when fertilizing heavier soils.

Figure 4. TSNAs vs. nitrogen rates for three years, five locations.



Topping

Any effect of topping on TSNAs is indirect through the effect on alkaloid levels. Topping early and/or low increases alkaloids and would be expected to increase TSNAs. We do not have much data on this topic, but indications are that differences are small and unlikely to have much impact, especially with low converter varieties.

What the grower can do

The effect of topping on TSNA accumulation is relatively minor.

- Top as recommended for best yield and quality (see Topping and Sucker Control, page 46).

Maturity at Harvest

Several studies have shown that TSNAs increase with increased maturity at harvest. Earlier studies used unscreened seed, and we know that conversion increases with increased maturity. Current results show a similar, but smaller, response with the low converter varieties now in use. The increase in TSNAs with increased maturity is due mainly to the higher alkaloids in later harvested tobacco; alkaloids increase steadily after topping.

What the grower can do

Weather and availability of labor to cut the crop often limit the grower's choice of harvest date, but to the extent possible, harvest at the maturity for best yield and quality.

- **Burley.** Typically, the best compromise between yield and quality is approximately three and a half to four weeks after topping.
- **Dark air-cured.** Harvest by five to six weeks after topping–some early maturing varieties may require earlier harvest.

- **Dark fire-cured.** Harvest by six to seven weeks after topping–some early maturing varieties may require earlier harvest.

Harvesting Practices

Field-wilting longer than necessary can, under some conditions, increase TSNAs. Figure 5 shows the TSNA accumulation in burley tobacco field-wilted for three and six days. These increases are small and are not always apparent, but it is advisable not to field-wilt burley longer than three days, as this can have a detrimental effect not only on TSNA accumulation, but also on leaf quality.

What the grower can do

Weather and availability of labor often dictate when the tobacco can be housed, but,

- House burley tobacco as soon as possible, ideally within a few days of cutting.

Air-Curing

Growing season and curing environment play a very large role in TSNA accumulation. Figure 2 shows the effect of season on a high and a low converter variety. At this location, 2005 was a year very conducive to TSNA accumulation; 2004 was not. The more than tenfold difference between years was due solely to environmental differences, as the same seed and growing practices were used in both years. Note that the low converter variety in 2005 (when conditions were highly conducive) still had lower TSNAs than the high converter in 2004 (when conditions were very unfavorable for TSNA formation).

The main factors affecting air-curing in relation to TSNAs are temperature, relative humidity, and air movement.

- Higher temperatures increase TSNAs because biological and chemical reactions are faster at higher temperatures.
- Higher humidity increases TSNAs because it is favorable for the nitrite-producing microbes and the leaf remains alive and active longer during curing, allowing more conversion of nicotine to nornicotine. Thus, with the increased nitrite and nornicotine available, more TSNAs are formed.
- Increased air movement decreases TSNAs mainly by increasing the drying rate of the leaf.

High humidity and high temperatures result in high TSNAs and often in houseburn. Low temperatures or low humidity result in low TSNAs but green or piebald tobacco. The conditions best for optimal quality (moderate temperatures and 72 to 75% relative humidity, i.e., a long, slow cure) are also favorable for TSNA accumulation. Under these conditions, TSNAs levels will be unacceptable if there is any appreciable amount of conversion. However, TSNAs will usually be acceptable if conversion is low and curing is well managed. Low converters can have significant amounts of TSNAs in conducive conditions if the curing is not properly managed (see Figure 2, low converter in 2005). The challenge is to produce quality tobacco with acceptable levels of TSNAs.

Packing rate in the barn impacts both humidity and air movement. In a humid curing season, such as 2017 in Figure 6, close stick spacing can significantly increase TSNAs, as well as causing houseburn. However, if the curing season is dry, such as 2015 in Figure 6, closer spacing may have no effect on TSNA accumulation.

Figure 5. Total TSNAs (ppm), for burley tobacco field-wilted for 3 and 6 days after cutting. Bars with different letters are significantly different at the 5% level.

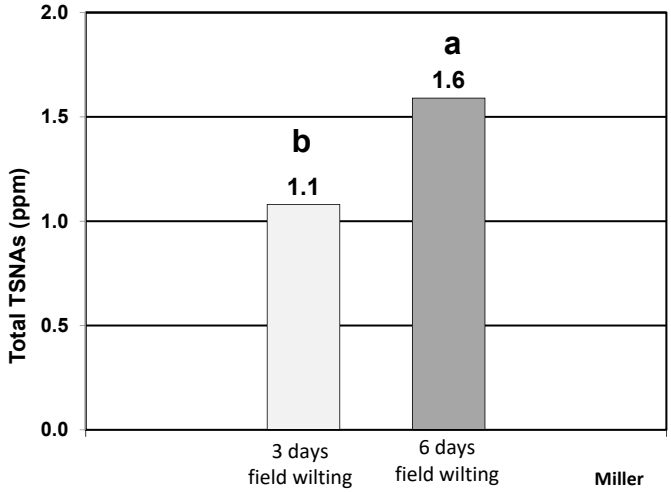
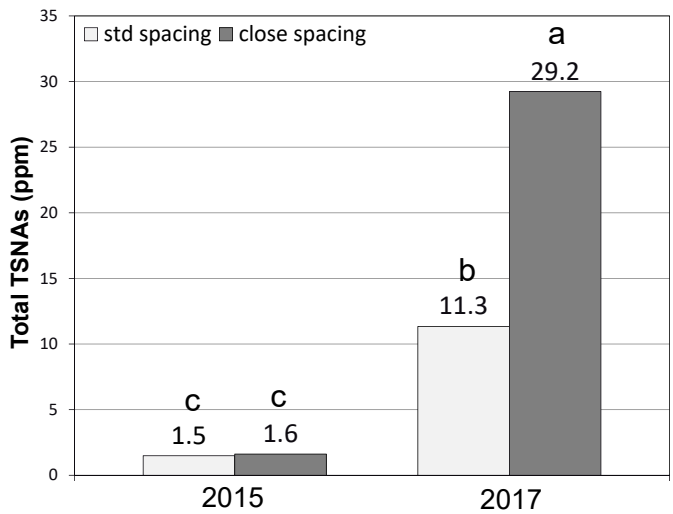


Figure 6. Total TSNAs for a high converter variety cured with standard and close stick spacing, over two years. Bars with different letters are significantly different at the 5% level.



Tests have shown that TSNAs in outdoor burley curing structures are very similar to those in a conventional barn (Figure 7) if they are in the same vicinity and experience similar environmental conditions.

The location and orientation of a barn can have a considerable effect on TSNAs by affecting the amount of ventilation. There can be big differences in TSNAs between tobaccos cured in different barns. TSNAs will tend to be lower in exposed barns on ridges and higher in barns in protected hollows with limited air movement.

Various barn modifications have been tested, but none have yet resulted in a practical and economical system to consistently reduce TSNAs while producing quality tobacco.

What the grower can do

Attention has focused on ventilation, because there is little that a grower can do to control ambient humidity and temperature during air-curing. However, ventilation can only be manipulated to a limited extent if quality is to be maintained. Managing curing specifically for very low TSNAs will often result in poor quality tobacco, so the best curing management is a balance between enough humidity for good quality and enough ventilation to minimize TSNA formation. Take the following steps:

- Space plants evenly on sticks, and space sticks evenly on the rails.
- Avoid packing sticks too closely (actual stick spacing will vary with barn design and size of tobacco).
- Manage vents to ensure adequate but not excessive ventilation.

Figure 7. NNN (ppm) in a conventional barn (left) and outdoor curing structure (right).

Fire-Curing

Fire-curing of dark tobacco involves the burning of hardwood slabs and sawdust on the floor of the barn during curing. Although fire-curing barns have bottom and top vents, they are typically much tighter than air-cured barns and most have metal siding. Many fire-cured barns are also equipped with fans in the top of the barn that can be used to increase ventilation early in the cure.

TSNAs

Although differences in barn design and the fire-curing process itself allow more control over curing conditions and less influence of outside weather conditions, the growing season and curing environment still play a major role in TSNA accumulation in fire-cured tobacco.

Fire-curing allows more potential for TSNA accumulation than air-curing. Higher temperatures are involved, which increases the speed of biological and chemical reactions, and nitrogen oxide (NO_x) gases are produced by the burning of wood, which increases nitrosation of tobacco alkaloids. However, some basic management practices for fire-curing can reduce the potential for high TSNA formation.

Avoid packing sticks too closely in the barn, as this can lead to poor cured leaf quality, losses in cured leaf weight, poor or uneven smoke finish on leaves, and higher TSNAs.

Ideally, start firing within seven days after housing. Avoid firing the tobacco more or longer than necessary to produce cured leaf with acceptable quality and marketability. Growers should strive to keep barn temperatures below 130°F, even during the drying stage of the cure. Ideally, tobacco should not be kept at 130°F longer than four to five days; by seven days at this temperature, TSNAs would be expected to increase. Figure 8 shows the effect that excessive heat during fire-curing has on TSNAs. All other factors being equal, tobacco in a barn that was allowed to reach 190°F during firing had NNN and total TSNAs that were nearly three times higher than tobacco in a barn that only reached 130°F.

Artificial casing with overhead misting systems or steamers is often required for takedown in dark fire-cured tobacco due to the extremely dry condition of the tobacco after curing is complete. This is particularly true with first cures in double-crop curing, where takedown needs to occur quickly following curing. Research has shown that use of overhead misting systems at takedown may result in lower TSNAs than steam.

Figure 8. Effect of excessive heat during fire-curing on NNN and total TSNAs.

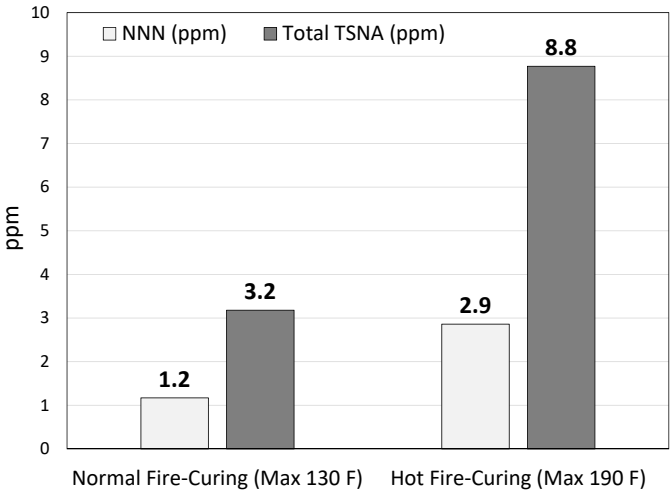
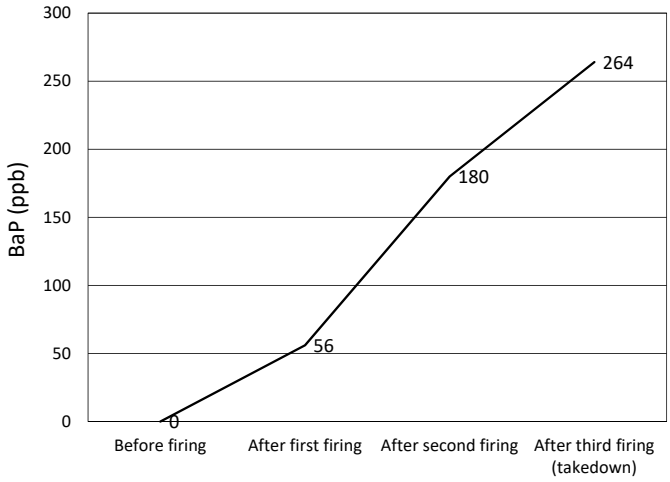


Figure 9. Increase in BaP over time during fire-curing. Tobacco was fired over 21 days using conventional fire-curing practices. Maximum temperature during firing was 133°F.



BaP

Benzo-α-pyrene (BaP) is another carcinogen, but is only found in fire-cured tobacco. BaP is a polycyclic aromatic hydrocarbon that is the result of incomplete combustion of organic material such as wood used in fire-curing. In general, BaP increases with the number of firings that are used, or the length of time that a barn is fired. Therefore, do not fire tobacco any more than is necessary. Figure 9 shows the general trend of how BaP increases with each firing.

What the grower can do – TSNAs

The most effective steps a grower can take are to minimize the effects of high temperatures (which increase the speed of TSNA-forming reactions) and wood combustion (which increases the amount of nitrosating agent). Do the following:

- Fire dark tobacco no more than necessary.
- Ideally, start firing within seven days after housing.
- Strive to keep barn temperatures in fire-cured barns below 130°F.
- Ideally, do not keep temperatures at 130°F for longer than four to five days.
- Space plants evenly on sticks, and place sticks evenly on the rails.
- Avoid packing sticks too closely.
- Use minimal artificial casing.
- Consider using overhead misting systems instead of steam when artificial casing is needed in fire-cured tobacco.

What the grower can do – BaP

Excessive firing is associated with higher BaP levels.

- Do not fire tobacco any more than is necessary.

Control of Microbes

The nitrite-producing microbes are ubiquitous and cannot be avoided. They are endophytic (inside the leaf), which makes application of any treatment very difficult.

Many chemicals and biological agents have been tested, but none of them has yet resulted in a practical control method. Correct curing will help to control microbes.

What the grower can do

At this point, there is no treatment to directly control the nitrifying microbes.

- Manage curing for production of high quality, full flavor and aroma tobacco, and avoid houseburn conditions that are conducive to microbial activity.

Moisture and Storage

Studies have shown that housing wet tobacco can increase TSNAs, as can storing high-moisture tobacco. It is difficult to control the moisture content of tobacco when using artificial methods of casing, such as steam or water sprays, and over-application of water to cured leaf can result in unsafe moisture levels during storage. For this reason, it is better to use natural casing if possible.

TSNAs generally increase with time in storage, although this is less evident in low converter tobacco. Tobacco should therefore not be left in storage longer than necessary.

What the grower can do

The following steps will help to minimize the effects of moisture on the nitrite-producing microbes:

- To the extent possible, do not house tobacco with free moisture on the leaves.
- Allow air-cured tobacco to come into case naturally if possible. If using artificial casing, avoid over-applying moisture.
- Use minimal artificial casing for fire-cured tobacco, and consider using overhead misting systems instead of steam.
- Strip, bale, and deliver tobacco as soon as possible to avoid any extra time in storage.
- Keep moisture in the cured tobacco as low as possible, ensuring that it is below the level specified in the contract.

Best Management Practices for Minimizing TSNAs

TSNA formation is a very complex process, and one cannot consider any of the factors contributing to it in isolation. All of these factors interact, and that is why different treatments sometimes result in TSNA differences and sometimes do not. These practices will contribute to lowering TSNAs:

- Use LC or screened seed.
- Choose the most suitable variety with the appropriate disease resistance package—if KT 204LC meets other requirements, the choice of this variety may help to lower TSNAs.
- Use no more nitrogen than necessary to optimize yield.
- Use muriate of potash at 100 lbs/acre in spring applications, with the remainder of the potassium recommendation coming from sulfate of potash.
- If sidedressing, apply nitrogen within four to five weeks after transplanting.
- Top correctly.
- Harvest at correct maturity, ideally about three and a half to four weeks after topping for burley, about five to six weeks for dark air-cured, and about six to seven weeks for dark fire-cured.
- House burley tobacco as soon as possible, ideally within a few days of cutting.
- To the extent possible, do not cut or house tobacco with free moisture on the leaves.
- Manage air-curing carefully, ensuring adequate but not excessive ventilation, and avoid houseburn.
- Avoid overpacking the barn, and space sticks and plants on the sticks evenly.
- Fire dark tobacco no more than necessary, this will also minimize BaP.
- Ideally, start firing dark fire-cured tobacco within seven days after housing.
- Strive to keep barn temperatures in fire-cured barns below 130°F.
- Ideally, do not keep temperatures in fire-cured barns at 130°F for longer than four to five days.
- Allow burley tobacco to come into case naturally and use minimal artificial casing for dark tobacco, ideally misting systems instead of steam.
- Do not leave tobacco in storage longer than necessary; strip, bale, and deliver tobacco as soon as possible.
- Keep moisture in the leaf as low as possible; do not put high-moisture tobacco into storage, and do not deliver tobacco with moisture higher than specified in the contract.

Cigar Wrapper Tobacco Production

Andy Bailey, Bob Pearce, and Matthew Vann

Introduction

There has always been a niche market for cigar wrapper leaf from dark fire-cured and, to a lesser extent, dark air-cured tobacco in the Kentucky/Tennessee dark tobacco production area. Major counties for dark tobacco cigar wrapper production include Robertson, Montgomery, and Cheatham counties in Tennessee, and Logan and Todd counties in Kentucky. Recently, there has also been a major interest from tobacco dealers in purchasing Connecticut Broadleaf cigar wrapper tobacco produced in Kentucky and Tennessee. Connecticut Broadleaf is an air-cured type that has traditionally been grown in areas of the Connecticut River Valley in Connecticut and Massachusetts. However, decreased production in that area along with increased demand for natural leaf cigar wrappers has caused tobacco dealers to pursue other tobacco-producing areas for this type. At first glance, Connecticut Broadleaf tobacco resembles dark air-cured tobacco, but generally has enhanced leaf quality characteristics that can increase its potential value for use as cigar binders and wrappers. In this chapter, we will focus primarily on Connecticut Broadleaf cigar wrapper tobacco, although many of the production principles discussed would also apply to dark cigar wrapper crops.

Leaf grades, characteristics, and projected prices

Wrapper is the term used to describe very high-quality tobacco leaf that is used for the outer layer of a cigar, which is the most visible portion. Depending on leaf quality, two to eight wrappers may be cut from a single leaf of tobacco. Binder leaf may also include a small number of wrappers but is primarily used just inside the outer wrapper leaf of a cigar, while the remainder of the cigar inside the binder is known as filler. Prices offered for cigar wrapper and binder grades are quite high ($4 to $6/lb) compared to current prices offered for dark and burley tobacco. However, prices offered for cigar filler are considerably less than current prices for dark and burley tobacco ($1.75/lb or less). Premium (#1) wrapper will contain six to eight wrapper "cuts" per leaf, while #2 wrapper/binder will contain two to five wrapper cuts per leaf. See Figure 1 for illustration of area of a wrapper cut on a leaf. Total yields of Connecticut Broadleaf tobacco are relatively low at around 2000 lbs per acre, or less. Therefore, profitability is completely dependent on the amount of wrapper/binder grades produced. To be profitable, growers producing Connecticut Broadleaf tobacco should strive for at least 50% wrapper/binder grades.

To be considered cigar wrapper, leaves must be at least 9 inches wide, have uniform brown color, excellent elasticity (stretch) throughout the leaf, be relatively thin, and be free of flaws such as holes, bruises, sunburn, disease spots, flecking, watermarks, or mixed color areas. For this reason, extreme care during harvest and handling are very important to prevent any damage to leaves that may have potential to become wrapper leaves. Leaves that are of sufficient size to qualify for wrapper grades will usually be found in the upper half of the stalk, while binder grades may come from the upper or mid-stalk portions.

Figure 1. Area of wrapper 'cut' in relation to cured leaf of Connecticut Broadleaf tobacco. Premium (#1) wrapper requires at least six wrapper cuts per leaf while #2 wrapper/binder requires at least two.

General Production Guidelines

Varieties

Although Connecticut Broadleaf variety trials have been conducted in Kentucky and North Carolina in 2019 and 2020, there is currently little or no variety selection in Connecticut Broadleaf like we are accustomed to with burley and dark tobacco. Up to this point, the dealer offering the contract supplies seed of one variety to the grower. This seed is usually the dealer's selection of a standard variety that has been grown in the traditional production area for many years. No Connecticut Broadleaf variety has any resistance to black shank. Therefore, Connecticut Broadleaf should only be grown in fields that have absolutely no known history of black shank. The current seed being provided is a selection of a variety known as '33', which only has disease resistance to tobacco mosaic virus (TMV).

Transplant Production

Production of Connecticut Broadleaf transplants in the float system is similar to production of dark or burley tobacco transplants, so the same general guidelines for transplant production should be followed. However, Connecticut Broadleaf varieties grow considerably faster in the float bed and in the field. Growth of this type tends to be a week ahead of dark and burley tobacco in the float bed and requires earlier clipping. In addition, Connecticut Broadleaf tends to set buds closer to the top of the plant than burley and dark tobacco, making it more difficult to manage plant height if clipping begins later than it should. To minimize clipping problems, Connecticut Broadleaf and burley or dark types should not be grown in the same float bed. In addition, Connecticut Broadleaf should be seeded one week later than burley and dark tobacco in order for the desired transplanting dates to be consistent across types and to prevent excessive growth in the greenhouse. Standard float bed fertility programs and spray programs recommended for dark and bur-

ley tobacco are also appropriate for Connecticut Broadleaf (see Management of Tobacco Float Systems, page 11). Confer with the buyer for more specific information or restrictions on the use of certain products.

Field Production

Site Selection

As with burley or dark tobacco, it is advisable to put Connecticut Broadleaf in fields that have good soil drainage, been out of tobacco for at least 2 years, and have no history of black shank and minimal history of target spot, frogeye leafspot, or angular leafspot. Fields with windbreaks that provide some protection from severe storms and wind are also advised.

Fertilization

Since cigar wrapper tobacco leaves need to be thinner and leaf yields are expected to be lower, nitrogen recommendations are less than those used for dark or burley. Our 2019 research results suggest that optimal total nitrogen for Connecticut Broadleaf should be between 150 and 175 lbs N/acre (Table 1). Although total yield may increase slightly, percent wrapper/binder yield tends to decrease at nitrogen rates of 200 lbs N/acre or more. All of the nitrogen can be applied prior to transplanting, or applications can be split with half to two-thirds applied prior to transplanting and the remainder applied at 2 to 3 weeks after transplanting. Phosphorus should be applied according to soil test recommendations for burley or dark tobacco. Some Connecticut Broadleaf contracts recommend applying 200 to 225 lbs potassium per acre regardless of soil test recommendations, although we do not currently have data that compares this recommendation to a standard soil test recommendation for potassium. Sulfate-of-potash (0-0-50) is the recommended potassium source. Soil pH recommendation for Connecticut Broadleaf is the same as that for dark and burley (6.2 to 6.6).

Table 1. Yield and percent wrapper results from 2019 Connecticut Broadleaf nitrogen rate trial, UKREC, Princeton.

Nitrogen Rate (Total lbs N/A)	Pre-Transplant N (lbs N/A)	Sidedress N (lbs N/A)	Total Yield (lbs/A)	% Wrapper/ Binder
75	75	0	1900	23
100	75	25	2002	34
125	75	50	2198	32
150	75	75	2052	36
175	75	100	2261	37
200	75	125	2145	29
225	75	150	2339	29
$LSD_{0.10}$ =			334	9

Transplanting

Standard plant populations for Connecticut Broadleaf fall between those currently recommended for dark and burley tobacco. Recommended plant population is between 6,000 and 6,400 plants per acre. This is approximately 24 to 26-inch plant spacing on 40 to 42-inch rows. Since more preventative pesticide applications are recommended for Connecticut Broadleaf, growers should consider leaving roadways or spray rows in the field to avoid damaging leaves from driving the sprayer through the tobacco.

Pest Control

Weed control programs recommended for use in burley and dark tobacco are also recommended for cigar wrapper tobacco (see Weed Management, page 27). Although much emphasis is placed on integrated pest management (monitoring for pest presence and thresholds before pesticide applications are made) for dark and burley tobacco crops, preventative applications are the key for cigar wrapper crops like Connecticut Broadleaf. Most successful Connecticut Broadleaf growers will be making fungicide or insecticide applications every 7 to 14 days throughout the season. Residual insecticides such as imidacloprid (Admire Pro or generics) or thiamethoxam (Platinum) should be used as tray drench or transplant water applications for residual aphid and flea beetle control, as well as chlorantraniliprole (Coragen) in transplant water applications for residual worm control. Ridomil Gold SL or Orondis Gold should be used in transplant water as preventative insurance against black shank and Pythium but remember first and foremost that Connecticut Broadleaf tobacco should not be transplanted into fields with any history of black shank.

During the season, routine foliar applications of insecticides such as acephate (Orthene), acetamiprid (Assail), or cyantraniliprole (Exirel) can be used for prevention of flea beetles and worms. Fleabeetles occurring late in the season and leaving pin holes in potential wrapper leaves have become a major concern with cigar wrapper tobacco. Preventative insecticide applications should be used to prevent fleabeetle damage throughout the season. Acceptable late-season flea beetle control may also require higher spray volumes than those used for worm control, as flea beetles tend to be found more toward the bottom of the plant late in the season.

Preventative applications of azoxystrobin (Quadris and generics) fungicide, alternated with mancozeb (Manzate) fungicide, should be used to preventatively manage frogeye leafspot and target spot. Up to three field applications of azoxystrobin can be applied at 8 oz/acre per application, with Manzate applications (2 lb/100 gallons per application) made between azoxystrobin applications. However, preharvest intervals limit the number of applications that can be made. Quadris can be applied no later than 21 days prior to harvest and Manzate can be applied no later than 30 days prior to harvest. Be aware that Quadris fungicide has the potential to cause flecking injury on leaves under certain conditions. Always apply Quadris alone with nothing else in the spray tank, and do not apply in the heat of the day (between 10 am and 5 pm on hot, sunny days), or with excessive pressure. If blue mold threatens (is found within 100 miles), growers should be prepared to apply blue mold fungicides such as mandipropamid (Revus). Fluopicolide (Presidio) can be used in soil applications after transplanting for black shank prevention or as foliar sprays for blue mold management. Although angular leafspot has not been a common problem in Connecticut Broadleaf in KY and TN so far, the crop is susceptible and growers should be prepared to make preventative applications of streptomycin (1 lb per 100 gal water) ahead of damaging storms in areas where angular leafspot is a concern. Repeated applications will be necessary if angular leafspot is confirmed.

Based on grower experiences and research conducted in 2019 and 2020, Connecticut Broadleaf may be more susceptible to late-season Frogeye leafspot infections that can result in "green speck" in the cured leaf (Figure 2). These leaves would obviously not be graded as wrapper or binder. For this reason, most should consider a final Quadris application near the 21-day preharvest interval. Confer with the buyer for more specific information or restrictions on the use of certain products. 2019 and 2020 research results showed a strong positive response to Quadris application both in total yield and wrapper/binder percentage (Tables 2 and 3). In 2019, one Quadris application at layby (4 weeks after transplanting) was better than no fungicide applications at all, but highest yield and percent wrapper/binder came from two applications of Quadris (at layby and at 21 days prior to harvest) with a Manzate application in between (Table 2). Increased yield and percent wrapper in this trial was a direct result of less green speck in the cured leaf when more fungicide applications were made. Similar results were seen in 2020, although wrapper percentage was lower overall due to weather damage. An additional treatment was added in 2020 that included six fungicide applications with an early Manzate application at three weeks after transplanting and post-topping applications of Revus and Double Nickel in an attempt to reduce 'green speck' in cured leaf (Table 3). 'Green speck' is currently the primary problem that limits the wrapper percentage in Connecticut Broadleaf grown in KY and TN. We are confident that this problem is associated with late-season infections of Frogeye leafspot and, therefore, fungicides that have activity against this disease should reduce 'green speck' and our fungicide trials appear to confirm this. However, other factors, such as humidity management during early curing stages, may also be associated with green speck in the cured leaf. Other research is currently being conducted to evaluate how curing conditions influence 'green speck'.

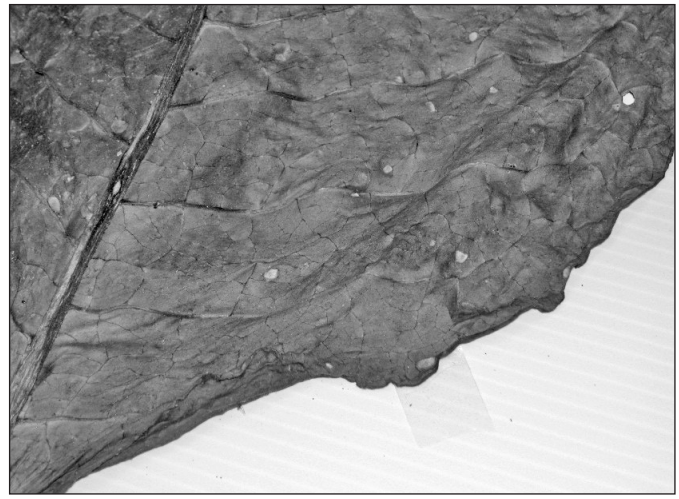


Figure 2. "Green speck" on cured leaf associated with late-season Frogeye leafspot infection.

Topping and Sucker Control

Connecticut Broadleaf is a very early flowering and fast-growing tobacco in the field. Where dark tobacco may be ready to top in about nine weeks, Connecticut Broadleaf may be ready to top in about seven weeks after transplanting. Lower topping heights result in larger leaves and are a standard practice for cigar wrapper tobacco. Early-flower topping should be the target for Connecticut Broadleaf, and plants should be topped down to 12 to 14 usable leaves per plant. For sucker control, manual stalk rundown applications of fatty alcohols (Off-Shoot T, Sucker Plucker, Fair 85, Royal Tac M) and local systemics (Prime+, Butralin, or Drexalin Plus) with backpacks or droplines are recommended. Remember that fatty alcohols and local systemics require direct contact with suckers at every leaf axil to be effective. Foliar spray applications of these products or applications of MH are not recommended due to undesirable effects on leaf size and texture.

For manual stalk rundown applications with droplines attached to spray booms, attach rubber tubing eight to ten feet long where nozzles are connected to the spray boom. Attach a trigger attachment (with or without a short "wand" attachment) to the end of the tubing (these are available in plastic and brass from the spray parts section of many farm supply stores). A large orifice nozzle can be attached to the trigger or trigger/wand attachment, but no nozzle at all can also be used. Use very low pressure (10-12 psi or less). If tobacco is straight,

Table 2. Yield and percent wrapper results of 2019 Connecticut Broadleaf fungicide trial, UKREC, Princeton.

Treatment	Rate	Timing	# Fungicide Applications	Total Yield (lbs/A)	% Wrapper/ Binder
No foliar fungicide	-	-	0	2065	33
Quadris	8 oz/A	Layby (4 wks)	1	2357	39
Quadris Manzate Quadris	8 oz/A 2 lb/100 gal 8 oz/A	Layby (4 wks) 5.5 wks Topping (7 wks)	3	2532	42
$LSD_{0.10}$ =				423	10

Table 3. Yield and percent wrapper results of 2020 Connecticut Broadleaf fungicide trial, UKREC, Princeton.

Treatment	Rate	Timing	# Fungicide Applications	Total Yield (lbs/A)	% Wrapper/ Binder
No foliar fungicide	-	-	0	1333	0.2
Quadris	8 oz/A	Layby (4 wks)	1	1488	3
Quadris Manzate Quadris	8 oz/A 2 lb/100 gal 8 oz/A	Layby (4 wks) 5.5 wks Topping (7 wks)	3	1591	9
Manzate Quadris Manzate Quadris Revus Double Nickel	2 lb/100 gal 8 oz/A 2 lb/100 gal 8 oz/A 8 oz/A 2 lb/A	3 wks Layby (4 wks) 5.5 wks Topping (7 wks) 8 wks 9 wks (preharvest)	6	1635	13
$LSD_{0.10}$ =				254	4

it only requires about ¾ ounce of solution per plant to get good rundown on stalks, and possibly even less with short plants of Connecticut Broadleaf topped down to 12-14 leaves. Remember to provide adequate personal protective equipment (PPE) like gloves, eye protection, and disposable coveralls to protect workers from pesticide exposure when making manual stalk rundown applications.

Use of conveyor hoods that attach to spray booms over 3-nozzle arrangements to "funnel" the spray solution over the row and down the stalk have not shown consistent benefits in burley and dark tobacco research, but may be an option to consider for Connecticut Broadleaf growers that do not have the labor required for manual dropline or backpack applications. With lower topping heights used in cigar wrapper tobacco, plants may stay straighter and allow for adequate coverage of leaf axils down the stalk with conveyor hoods. See Topping and Sucker Control, page 46, for more information on sucker control.

Harvest

To achieve the correct leaf body and thickness, protect leaf integrity of wrapper leaves, and prevent leaf damage from weather in the field, Connecticut Broadleaf and other types grown for cigar wrapper need to be harvested fairly immature, no later than three weeks after topping. This type of tobacco will require field-wilting after cutting but before putting plants on sticks. Take precaution against sunburn by not cutting more than can be picked up quickly if sun becomes intense during field-wilting. Spike/spear as soon as tobacco is pliable enough to be put on sticks without breaking leaves. When cutting, ensure stalks are cut at ground level to prevent stumps from poking holes in wrapper leaves laid down to field-wilt. Place sticks in the row middle instead of over the row to avoid dragging plants over stumps. Load sticks onto scaffold wagons immediately after spiking/spearing and do not push sticks closely together to prevent bruising and leaf breakage. For assistance with constructing scaffold wagons, see https://www.uky.edu/bae/content/tobacco-plans#wagons Loaded scaffold wagons should be pulled into a shaded area for additional wilting for a day or so prior to housing/hanging in the barn. If shady areas are not available, wagons can be covered with shade cloth to prevent sunburn. Sticks should be housed/hung in air-curing barns with good ventilation. Use at least 10-inch stick spacing on the tier and consider skipping tiers in older dark tobacco barns that have short (3 ft.) vertical tier spacing.

Curing

More barn management during curing is required for Connecticut Broadleaf than for burley or dark air-cured tobacco. Take advantage of better weather conditions for curing when scheduling harvest. Make every effort to harvest Connecticut Broadleaf while weather is still warm for the best air-curing conditions. Target harvest by September 1 at the latest. Ideal curing conditions during the first four weeks of curing are daily average temperatures of 60 to 90 F and daily average relative humidity of 70 to 75%. For most of the curing season, barn doors and vents should be open during the day but consider closing doors and vents at night when humidity is high. If conditions become excessively dry (<60% average daily relative humidity), doors and vents may need to be closed during the day and open at night and water can be added to the barn floor. If conditions become excessively wet (>80% average daily relative humidity), consider using fans to move dry air through the tobacco.

During prolonged wet, high-humidity periods, it may be necessary to use moderate levels of heat in the barn to lower the humidity. Propane burners or small fires with dry wood or charcoal (limited smoke) can be used on the barn floor for short periods (6 to 8 hours at a time) to lower humidity during wet periods. Be careful not to expose Connecticut Broadleaf to excessive smoke when heating with wood.

Market Preparation

2019 experience suggests that sorting wrapper/binder and filler grades in a crop of Connecticut Broadleaf takes between 2 and 2.5 times longer than stripping a typical crop of dark or burley tobacco. In 2020, leaf dealers contracting Connecticut Broadleaf tobacco allowed growers to use a 'straight strip' sorting method to reduce time spent sorting wrapper and non-wrapper leaves. With this method, growers will strip off and segregate the trash leaves at the bottom of the stalk, then the obvious filler leaves in the lower stalk. All of the leaves in the top half of the stalk that may have potential to be wrapper leaves will be stripped together and oriented in C48 cardboard boxes or other marketing packages the dealer supplies. At delivery, the dealer will collect samples from these boxes to make a determination of the percent wrapper grades in the crop and set the price per pound accordingly. Higher prices will be offered for crops with higher percent wrapper leaves based on samples taken at delivery. Contact the dealer for specific questions on market preparation requirements.

Summary

Connecticut Broadleaf and other cigar wrapper tobacco types may be profitable for Kentucky and Tennessee growers that use detail-oriented management approaches. However, Connecticut Broadleaf is a new type of tobacco that requires more management considerations, fungicide/insecticide applications, and labor than the traditional types grown in Kentucky and Tennessee. The shortened field season for Connecticut Broadleaf may allow some labor efficiency where harvest of this type can be complete before burley or dark tobacco harvest begins. We are still learning about optimal production methods for Connecticut Broadleaf tobacco in Kentucky, Tennessee, and other areas. For tobacco growers considering Connecticut Broadleaf, it is advised to start small with no more than 1 or 2 acres, as this is a high risk, potentially high reward crop. Growers are advised to have good communication with their buying company for this type of tobacco and be sure to understand the terms of their contract. Buyers may have very specific preferences for the types of pesticides used and other management practices.

Safety and Health in Tobacco Production

Bob Pearce and Wayne Sanderson

Production agriculture is a hazardous business. While tobacco production may not be especially hazardous in terms of fatalities compared to other crops, the range of operations required for the production of a crop is quite varied. Tobacco production requires significantly higher amounts of manual labor than other field crops, and thus carries a significant opportunity for accidents and injuries. Tobacco harvesting and stripping operations, in particular, typically require large crews of seasonal labor, and it is important that these workers are aware of potential hazards and use safe working practices. Communication can be difficult with large and varied work crews, especially with immigrant laborers who may not understand English well, so farm operators must put effort into promoting safety.

Safety during Tobacco Setting

Tobacco setting is a relatively safe operation. However, protection from heat and sun and proper hydration are important and will be discussed below in the section "Harvest Field Safety and Health."

Research has uncovered several cases of carbon monoxide poisoning during setting operations. Although you may think carbon monoxide poisoning is impossible outdoors, utility tractors with underslung mufflers and exhaust pipes can pump carbon monoxide directly into your workers' breathing zone. Only use tractors with vertical exhausts during setting.

Preharvest Preparation

The most important safety work you can do on your farm is preseason preparation. The old saying, "An ounce of prevention is worth a pound of cure," is certainly applicable here. Doing what is necessary to create a safe workplace will help you avoid many in-season injuries that cost time and money.

Prior to hanging tobacco, carefully inspect the rails (and all related structural members) of your barns for cracks and damage, and be sure they are not loose, since broken or loose rails or related structures are a major cause of falls while hanging tobacco. Needless to say, these falls can be extremely serious and can result in broken necks, permanent paralysis, or death. Do not assume that the rails and related members are in the same condition they were last year. Look them over carefully and repair or replace rails and related members with even a small amount of weakness. Make sure they are securely attached. Look for locations where ladders or steps can be efficiently added to the barn to reduce the amount of climbing around on the rails, especially in very large barns that have become more common in burley tobacco production. To date, no workable personal fall protection systems have been developed for conventional burley tobacco barns, so the condition of the rails and related members are crucial in protecting workers. This cannot be emphasized enough.

Check the barn for bee or wasp nests, especially around and under eaves. Tobacco housing activities can disturb bees and wasps and result in painful stings for workers. Safely remove any known nesting areas. Long-distance, quick knockdown insecticides work well to reduce the chance of stings.

Inspect wagons and other equipment used during harvest. For wagons, inspect the deck itself, look for cracked or broken floorboards or other wooden parts, and make sure that the rear rack is sound and secure. Check the running gear, including rims, tires, and tire pressures. The last thing you want in the middle of harvest is to have a wagon go down from some sort of failure. A breakdown on the road while transporting a load of tobacco is even more dangerous. If you pull more than one wagon at a time, the hitch on the rear of the leading wagon must be in good condition, since it is pulling the wagon behind it. You should have safety hitch pins (pins with retainers so they cannot pop out) for all your wagons. You should have a bright and clean SMV emblem on all wagons, especially the rear-most wagon if pulled in tandem. Don't leave safety issues to chance.

Before dropping sticks from your Hi-Boy or other machine, make sure the machine itself is in good working condition, especially steering systems and wheels/tires that could lead to a failure or loss of control if they malfunction. Make sure you have safe, comfortable accommodations for the riders. Just because you've always done it this way does not mean improvements cannot be made. Does the machine have sturdy, comfortable seats that don't wobble or do anything else that could lead to a fall? Are the seats padded for comfort over rough ground? Do they have footrests to support feet and legs? Can they climb on and off safely, with proper places for their feet and handrails to hold on? Falls while mounting and dismounting machinery are important causes of injury and can be very serious. While seatbelts are not recommended for tractors and other machines that do not have roll-over protective structures (ROPS), your riders should be provided with handrails or other places to hold on to while going over rough ground. Are the sticks not only secure but convenient in order to prevent excessive reaching and other awkward movements that can lead to sore muscles or falls? Can the sticks fall on the riders or driver? Be sure they are secured in some manner.

Harvest Field Safety and Health

Tobacco harvest involves both injury and illness hazards. Hazards like the tobacco knife and spear point at the end of sticks may seem obvious but should be discussed with workers prior to harvest. It never hurts to remind workers that rushing, lack of attention, or horseplay in the field can result in a serious cut or spearing. Eyes are especially vulnerable to the spear and cannot be replaced once they've been destroyed. Stylish safety glasses, including safety sunglasses, are available from online safety equipment suppliers at very reasonable prices and would be a good way to protect workers' eyes.

Heat and sun exposure are other obvious hazards that should be discussed with workers. Wearing hats that cover the ears reduces sun exposure that has resulted, over the long term, in high rates of skin cancer among farmers. Hydration is critical; plenty of water should be available at all times, and workers should be encouraged to take breaks and stay hydrated. In the military, field personnel in hot climates are *ordered* to stay hydrated; it is not an option. Problems that can result from excessive heat

include heat rash, which is skin irritation from excessive sweating; heat cramps; heat exhaustion, which has symptoms such as heavy sweating, rapid breathing, and a fast but weak pulse; and heatstroke, a life-threatening illness resulting from very high body temperatures which can have symptoms like dizziness, dry skin, and a rapid but strong pulse. Heatstroke requires immediate emergency care to prevent death.

Green tobacco sickness is a type of nicotine poisoning resulting from contact with wet tobacco, particularly when workers' clothing becomes saturated. Symptoms vary but may include nausea, vomiting, dizziness, headache, weakness, and cramping. Saturated clothing should be removed, the skin washed with soap and water, and dry clothing provided. Although the illness is not life-threatening and will normally resolve itself in a few days, medical care should be provided, since other factors might be involved, especially if symptoms are severe. Preventing green tobacco sickness means waiting until leaves are dry before harvesting or wearing a rain suit when working in wet tobacco.

Safety in the Tobacco Barn

As discussed previously, rails and related structural members should be inspected prior to hanging tobacco, and any repairs or replacements made. Workers should be required to wear sturdy shoes with good soles that provide traction on the rails. Three points of contact should be maintained when climbing in the barn, either two feet and one hand or one foot and two hands. Frequent rest breaks are recommended to avoid leg fatigue that may lead to falls while up in the barn. Horseplay should not be allowed in the barn, especially during climbing, hanging sticks, or just waiting for the next load. The same applies when removing the cured tobacco from the barn. Needless to say, the consumption of alcohol or illegal drugs during barn operations must be absolutely prohibited.

Stripping and Market Preparation

The same precautions for housing tobacco in traditional barns apply when climbing back in the barns to bulk the tobacco for stripping. The hazards involved with traditional manual stripping operations are minimal, but if some of the newer, powered mechanical stripping devices are used, workers need to be protected from moving parts like gears and chains. Hearing protection may be required around powered stalk choppers, which can be very loud. Formable ear plugs or ear muffs reduce noise exposure by several decibels, protecting the ears from hearing loss. The big tobacco balers that have become much more common have pinch points that workers must be made aware of. Workers operating the hydraulic valves on these balers need to be sure that their coworkers are well clear of the balers when in operation. In general, any time machines are used in these operations, workers using them or working in the area should receive safety training, for their protection and yours.

Stripping may involve dusty conditions. Good ventilation and dust filtering are important to provide a safe and comfortable working environment and protect the respiratory health of workers. There are two options you can pursue.

In relatively small stripping rooms that tend to be very dusty, dust filtering systems like those used in woodworking shops, with replaceable disposable filters, may be an option. It is important that adequate filtering capacity, good quality filters, and regular filter changes are provided.

A second option is for workers to wear approved dust respirators (also known as dust/mist respirators or particulate respirators). These respirators must be approved by the National Institute for Occupational Safety and Health (NIOSH) and carry a NIOSH approval number. Do not use the inexpensive, non-approved dust masks which look similar but are used only for nuisance dusts like sawdust and are not considered respirators. Typically, these masks are very inexpensive, have a single strap, and do not seal well, whereas true dust respirators cost more and have two straps for a tighter fit. The mask must fit tightly around the user's nose and mouth, and cannot be used with beards or facial hair because a seal cannot be obtained.

Local or online safety companies can help you select the appropriate dust respirator, as there are several different ratings available. Typically the appropriate rating would be an N95 respirator, which means it is for non-petroleum mists/dusts (the "N" means Not resistant to petroleum) and is 95% effective when properly fitted, which is an acceptable level of effectiveness. An N99 or N100 dust respirator might be necessary for someone with severe allergies to dust or when working with more harmful dusts and molds. A "P" respirator, such as P95, is designed to be resistant to mists and dusts that contain petroleum products. An "R" respirator is in between, being somewhat resistant to petroleum products. Ask your safety supplier for guidance.

Roadway Safety

Farmers across the country know that operating farm equipment on public roads is stressful and sometimes dangerous as the general public becomes more removed from farming, and motorists often seem to care more about personal convenience than safe driving or sharing the road. Cell phones and other distractions make the situation even worse. Smart farm operators take precautions to protect themselves as much as possible during roadway transport.

One important aspect of roadway safety is proper lighting and marking. Equipment should be as visible as possible to motorists approaching from the front or rear. Remember that crop materials like tobacco or round bales tend to blend in with the surrounding terrain. All tractors, wagons, and any tall implements that block a motorist's view of the tractor must have bright slow-moving vehicle (SMV) emblems. These emblems must be kept clean and replaced when they fade. High-visibility tape, including bright fluorescent orange for daytime and reflective yellow/amber and red for dusk and nighttime, should be added to the extremities of equipment to help motorists see the width of the equipment and prevent collisions when passing. Lights should be in working condition and used day and night; use your headlights, taillights, and flashing amber lights any time you are on the road, to make equipment more visible. Rotating amber beacons are excellent additions to help attract attention. The only lights that should not be used on the road are work lights that are intended for field use only, since they will blind or impair the vision of approaching motorists.

Another important aspect of roadway safety is maintaining control of equipment. First and foremost, safety hitch pins (as mentioned previously, have retainers to prevent popping

out) should always be used to prevent wagons or other trailing equipment from coming unhitched. Do not use homemade hitch pins. Safety chains should be used with pickups, but are also advisable with tractors. Operators should be trained to slow down if wagons are swaying and not trailing properly. Speed must be kept down when navigating blind curves or hills, and the operator should be ready for traffic to appear.

Anyone operating your equipment should be knowledgeable about highway laws and follow all rules of the road. It is best (both for safety and liability reasons) to require anyone who will operate your equipment on public roads to have a driver's license. Examples of important operator skills and courtesies include allowing adequate time to pull across or onto roads, pulling over to allow following traffic to pass, and staying within the lane. Operators must have good judgment to know when it is safe to do any of these things, especially being aware when equipment is too wide to remain in a single lane and may interfere with oncoming traffic or strike roadside obstacles.

Besides the potential for serious injury or death, and interruption of operations, roadway collisions should be avoided because of liability. Even if you are innocent of any wrongdoing, a lawsuit can drown you in paperwork and legal costs, and take away from time needed to manage and operate your farm. Having your equipment involved in a serious collision following failure to obey traffic regulations, or other operator error, or as a result of failing to maintain equipment, exposes you to potentially serious liability.

Tractor Safety in General

The tractor rollover, or overturn, is the single most common fatal farm-related incident in the nation. For that reason, all tractors should be equipped with roll-over protective structures (ROPS), which are either roll bar-type frames or cabs with rollover protection built into the structure. Seatbelts should be worn when tractors have ROPS, but even if the operator is not wearing a seatbelt, a tractor with a ROPS is much safer than a tractor without ROPS. Tractors used on hillsides should have wider wheel spacings and be weighted properly; be sure to consult your owner's manual. The center of gravity must be kept low, especially when using a loader, and the operator should be trained to always turn downhill if the tractor feels unstable.

Hitching injuries can be avoided by making sure the person helping the tractor operator is not between the tractor and implement. Good communication, especially eye contact, should be maintained between the helper and the operator. Helpers should wait until the tractor stops before stepping between the tractor and the implement to hold the wagon tongue or hitch. Tractor operators should also be aware of bystanders, especially children, who should be kept away from farm equipment.

Falls from tractors and resulting run-overs are a common cause of farm fatalities. Extra riders should not be allowed on tractors unless there is a training seat in the cab; such seats are typically found only on newer, larger tractors. If it is necessary to get workers out to a field, use cars or other forms of transportation. Even if taking extra riders on tractors has been a common practice on your farm, it is a disaster waiting to happen and should be stopped.

Infectious Disease Risks

During the respiratory illness pandemic caused by a new virus commonly called COVID-19 (SARS-CoV-2) it became more important than ever for employers to be acutely aware of how to protect workers from infectious diseases. COVID-19 is a highly infectious virus with a relatively high mortality rate. It is spread through respiratory droplets produced when an infected person coughs, sneezes, or talks. Even people who are not showing symptoms can spread the virus. It may also be possible that a person can get COVID-19 by touching a surface or object that has the virus on it and then touching their own mouth or nose.

Farmworkers often have close, prolonged contact to one another through both their work activities and shared housing. Farm operators can prevent and slow the spread of COVID-19 by reducing or removing ways workers may be exposed to the virus. The best approach is to eliminate a hazard, such as by preventing contact with sick workers and visitors, installing feasible engineering controls like barriers and shields, and cleaning and disinfecting the work environment. The next level of control includes reducing the number of workers in an area, increasing the distance between them, or reducing the amount of time they must be in the same location. Finally, personal protective equipment such as masks and respirators may be needed. The same types of masks recommended for reducing exposure to dust particles are effective in reducing exposure to viral particles, when worn properly.

A basic screening procedure may also help reduce the exposure of farm workers. Asking workers in appropriate languages if they have had a fever (or feelings of feverishness), respiratory symptoms, or other symptoms in the past 24 hours or checking temperatures of workers at the start of each shift to identify anyone with a fever of 100.4° or greater can help identify workers who may be spreading the virus. Workers should be encouraged to report symptoms immediately, to self-isolate, and contact a healthcare provider. The Center for Disease Control and U.S. Department of Labor have provided guidance on action to protect agricultural workers from COVID-19 (https://www.cdc.gov/coronavirus/2019-ncov/community/guidance-agricultural-workers.html).

A video in English and Spanish is also available to help with planning for COVID-19 (SARS-CoV-2) prevention on-farm at the following links:

- English video on COVID 19: https://youtu.be/j3T6VtCVODo
- Spanish video on COVID 19: https://youtu.be/whHQ3y-bXsjk

NOTE: This section is intended to provide basic information and cannot cover every possible or potential hazard on your farm. Each farm operator is responsible for inspecting the entire farm, including related structures and equipment, for hazards, and for operating machinery according to manufacturers' specified practices.

A bilingual (English/Spanish) bulletin is available from UK Cooperative Extension: *Introductory Safety Training for Tobacco Workers* (ID-204). This bulletin provides basic training using a farm walk-around approach by the grower with the workers. It covers inspecting tobacco barns; inspecting tobacco wagons; inspecting the Hi-Boy sprayer used for dropping sticks; inspect-

ing tractors before use; tractor operation; safe tractor operation on roads; safe harvesting of tobacco; green tobacco sickness; heat illnesses; and dangers of sun exposure. The publication provides basic introductory training and is not intended to cover all possible hazards on a farm.

Video versions of ID-204 are available in both English and Spanish:

- Spanish: http://video.ca.uky.edu/videos/video/197/
- English: http://video.ca.uky.edu/videos/video/207/

Appendix I

Worker Protection Standard Updates

Ric Bessin

The Worker Protection Standard (WPS) was updated in 2015 and went fully into effect January 2, 2018. The Standard is a federal regulation designed to protect agricultural workers (people employed in the production of agricultural plants) and pesticide handlers (people mixing, loading, or applying pesticides or doing certain tasks involving direct contact with pesticides). Below is a summary of major provisions. Go to http://pesticideresources.org/wps/hosted/quickrefguide.pdf for a quick reference guide.

Duties for all Employers

The revisions to the Worker Protection Standard cover many different areas. The major revisions include:

- **Annual mandatory training** to inform farmworkers on the required protections afforded to them. Previously, training was only once every 5 years.
- Expanded training includes instructions to **reduce take-home exposure** from pesticides on work clothing and other safety topics.
- First-time ever minimum age requirement: **Children under 18 are prohibited from handling pesticides.**
- **Expanded mandatory posting** of no-entry signs for the most hazardous pesticides. The signs prohibit entry into pesticide-treated fields until residues decline to a safe level.
- **New no-entry application-exclusion zones** up to 100 feet surrounding pesticide application equipment will protect workers and others from exposure to pesticide overspray.
- Requirement to **provide more than one way** for farmworkers and their representatives **to gain access to pesticide information.**
- **Application information and safety data sheets**—centrally posted with unrestricted access, or by requesting records.
- **Mandatory record-keeping** to improve states' ability to follow up on pesticide violations and enforce compliance. Records of application-specific pesticide information, as well as farmworker training, must be **kept for three years.**
- **Anti-retaliation provisions** are comparable to Department of Labor's (DOL).
- **Changes in personal protective equipment will be consistent with OSHA's standards** for ensuring respirators are effective, including fit test, medical evaluation and training. Records must be keep for 2 years.
- **Specific amounts of water** to be used for routine washing, emergency eye flushing and other decontamination, including eye wash systems for handlers at pesticide mixing/loading sites.
- **Continue exemption for farm owners and their immediate families** with an expanded definition of immediate family.

Worker Protection Standard Checklist

This information was prepared to help farmers comply with the Environmental Protection Agency's Worker Protection Standard (WPS). It does not cover all details of the requirements. Sources and costs of signs and equipment are given as educational examples only. Prices vary with source and quantities purchased. See the WPS section of the label for product-specific requirements.

Notification—Signs for Posting Information at Central Location

- ☐ WPS Safety Poster
  Gempler's 230032..... $ 6.29 each
- ☐ Nearest Medical Facility Sign (or make your own)
  Gempler's X1584 .....$ 11.79 each
- ☐ Reusable Pesticide Application Poster (or make your own, see below)
  Gempler's P942-17.....$ 6.99 each
- ☐ Corrugated WPS Sign
  Gempler's 2256.....$ 3.99 each

All greenhouse applications require posting. Some labels require field posting. Posting must be done before application and remain until three days after REI expires. Signs must be visible from all entrances into treated areas.

- ☐ Oral notification—Inform workers of treated areas before application or before they begin work. Tell them location and description of treated area, date and times entry is restricted, Application Exclusion Zone, REI, and not to enter during REI. Some pesticide labels require both oral warnings and posting of treated areas. Post warning signs if the REI is greater than 48 for outdoor areas or 4 hours for enclosed areas.
- ☐ Pesticide handlers must understand all labeling information for the pesticides they are using and must have access to labeling.
- ☐ Decontamination supplies must be within a quarter mile of workers/handlers. Maintain for seven to 30 days after REI expires (see specific labels). Provide water that is safe and cool enough for washing, eye-flushing, and drinking

Workers must have water to wash hands (1 gallon per worker), soap, and single use towels. Must not be in area being treated or under REI.

Handlers must have water to wash entire body (3 gallons per handler), soap, single use towels, and clean coverall or change of clothes. Also must be where personal protective equipment is

removed and in mix/load area. Supplies must be enclosed. Handlers need decontamination supplies at mixing loading sites, where PPE is removed, and within ¼ mile of area being treated. When a product requires protective eyewear for handlers, and/or when using a closed system under pressure, handlers must have immediate access to supplies for eye-flushing.

Personal Protective Equipment (PPE)

Employer must provide and maintain clean PPE required by labels and a pesticide-free area to store and put on and take off equipment. Dispose of heavily contaminated PPE as hazardous waste. Check the label for specific PPE needed for mixing, loading, and application. Do not allow PPE to be taken home.

- ☐ Chemical resistant gloves (15 mil unlined nitrile)
  Gempler's 10212 ..... $ 2.99 (pair)
- ☐ Unhooded DuPont Tyvek Coverall
  Gempler's 214559 ..... $ 8.79 each
- ☐ Low-cost Anti-Fog Chemical Splash Goggles
  Gempler's 10507 ..... $ 3.79 each
- ☐ 3M Half Mask Pesticide Respirator
  Gempler's G10861 ..... $ 39.99 each
- ☐ Replacement cartridges with particulate filter
  Gempler's G60921 ..... $ 29.19 (2 cartridges)

Emergency Assistance—Act promptly if any worker/handler may be poisoned.

- ☐ Provide transportation to medical facility.
- ☐ Supply medical personnel with Safety Data Sheet (SDS), product name, EPA registration number, and active ingredient(s). Describe pesticide use and give details about exposure.

Training—Annual training required. Certified pesticide applicators do not need WPS training and can perform WPS training. Use EPA approved training materials available from your Extension office or at http://pesticideresources.org/wps/training/index.html.

- ☐ Workers need basic training **before** they begin work in an area which has had an active REI within the past 30 days. A worker is anyone who does tasks such as harvesting, weeding, or watering.
- ☐ Handlers mix, load, transfer, or apply pesticides. They also may do many other specific tasks, such as incorporating soil-applied pesticides, clean PPE, and dispose of pesticide containers.
- ☐ WPS Training Receipt
  Gempler's 10197-17 (worker) ..... $ 9.99 each

Sample Pesticide Application Poster.
Post before application is made, keep posted until 30 days after Restricted Entry Interval (REI) expires.

Field Location and Description	Crop or Site Treated	Product Name and EPA Registration Number	Active Ingredient(s) in Product	Date of Application	Start and End Times of Application	Duration of Restricted Entry Interval

Appendix 2

Information Summary Table for Tobacco Pesticides

The table on the following pages is provided for a quick reference to many of the pesticides labeled for use in tobacco production as of November 2020. This is a listing of the most commonly used pesticides and is not a total listing of all pesticides registered for use on tobacco. Listing of certain products and omission of others does not constitute a recommendation or endorsement. Pesticide labels change frequently so always check the label to insure the pesticide is currently registered for use on tobacco and to obtain appropriate rates and application instructions. Many products may have the same active ingredient(s), but have different use rates due to differences in the formulation. Pesticides in this table are listed alphabetically by brand name with additional information that may be required for Tobacco GAP and/or pesticide recordkeeping.

Use pesticide products only in accordance with their labels and with the Environmental Protection Agency Worker Protection Standard (WPS). Do not enter or allow worker entry into treated areas during the re-entry interval (REI). Check the label for Personal Protective Equipment (PPE) required for early entry to treated areas that is permitted under the WPS and involves contact with anything that has been treated, such as plants, soil, or water.

Crop Protection Agents (CPAs) Used in the Production of Tobacco

Trade Name (click for label)	SDS	EPA Registration No.	Type	Active Ingredient	Manufacturer	RUP[1]	Signal Word	Days PHI[2]	Hours REI[3]
Acephate 90 Prill	SDS	66222-123	insecticide	acephate	Makhteshim Agan of North America, Inc	No	Caution	3 days	24 hrs
Acephate 90 WDG	SDS	34704-1051	insecticide	acephate	Loveland Products	No	Caution/Warning	3 days	24 hrs
Acephate 90 WSP	SDS	34704-862	insecticide	acephate	Loveland Products	No	Caution	3 days	24 hrs
Acephate 97 WDG	SDS	66222-266	insecticide	acephate	ADAMA	No	Caution	3 days	24 hrs
Acephate 97UP	SDS	70506-8	insecticide	acephate	United Phosphorus, Inc	No	Caution	3 days	24 hrs
Actara 25 WG	SDS	100-938	insecticide	thiamethoxam	Syngenta Crop Protection, LLC	No	Caution	14 days	12 hrs
Actigard 50WG	SDS	100-922	plant activator/ fungicide	acibenzolar-S-methyl	Syngenta Crop Protection, LLC	No	Danger	21 days	12 hrs
Acumen	SDS	241-337-55467	herbicide	pendimethalin	Tenkoz, Inc	No	Caution	Not foliarly applied	24 hrs
Admire Pro 4.6F	SDS	264-827	insecticide	imidacloprid	Bayer Crop Sciences	No	Caution	14 days	12 hrs
Aframe	SDS	100-1098	fungicide	azoxystrobin	Syngenta Crop Protection, LLC	No	Caution	No restriction stated on label	4 hrs
Agree WG	SDS	70051-47	insecticide	Bacillus thuringiensis	Certis USA, LLC	No	Caution	No restriction stated on label	4 hrs
Agri-Mycin 50	SDS	55146-96	bactericide	streptomycin sulfate	Nufarm Ag Products	No	Caution	No restriction stated on label	12 hrs
Aim EC	SDS	279-3241	herbicide	carfentrazone	FMC Corp	No	Caution	Not foliarly applied to tobacco	12 hrs
Alias 2F	SDS	66222-203	insecticide	imidacloprid	ADAMA	No	Caution	14 days	12 hrs
Alias 4F	SDS	66222-156	insecticide	imidacloprid	ADAMA	No	Caution	14 days	12 hrs
Aliette WDG	SDS	264-516	fungicide	aluminum tris (O-ethyl phosphate)	Bayer Crop Sciences	No	Caution	3 days	12 hrs
Antak	SDS	19713-18	sucker control	C10 fatty alcohol	Drexel Chemical Co	No	Caution	7 days	24 hrs
Assail 30SG	SDS	8033-36-70506	insecticide	acatamiprid	United Phosphorus, Inc	No	Caution	7 days	12 hrs
Assail 70WP	SDS	8033-23-70506	insecticide	acatamiprid	United Phosphorus, Inc	No	Caution	7 days	12 hrs
Aza Direct	SDS	71908-1-10163	insecticide	azadirchtin	Gowan Co	No	Caution	No restriction stated on label	4 hrs
Belay Insecticide	SDS	59639-150	insecticide	clothianidin	Valent USA	No	Warning	14 days	12 hrs
Besiege	SDS	100-1402	insecticide	lambda-cyhalothrin + chloratrailiprole	Syngenta Crop Protection, LLC	Yes	Warning	40 days	24 hrs
Biobit HP	SDS	73049-54	insecticide	Bacillus thuringiensis	Valent USA	No	Caution	No restriction stated on label	4 hrs
Blackhawk Naturalyte	SDS	62719-523	insecticide	spinosad	Dow AgroSciences	No	Caution	3 days	4 hrs
Blanket 4F	SDS	82534-5-55467	herbicide	sulfentrazone	Tenkoz, Inc	No	Caution	Not foliarly applied	12 hrs
Brigade 2EC	SDS	279-3313	insecticide	bifenthirin	FMC Corp	Yes	Warning	Do not apply later than layby	12 hrs
Brigadier	SDS	279-3332	insecticide	bifenthrin + imidacloprid	FMC Corp	Yes	Warning	Do not apply later than layby	12 hrs
Butralin	SDS	33688-4-400	sucker control	butralin	Arysta Lifescience North America, LLC	No	Danger	30 days air-cured and dark tobacco types, 7 days flue-cured	12 hrs
Capture LFR	SDS	279-3302	insecticide	bifenthrin	FMC Corp	Yes	Danger	Do not apply later than layby	12 hrs

[1] RUP: Restricted Use Pesticide
[2] PHI: Pre-Harvest Interval
[3] REI: Restricted-Entry Interval

table continued on next page

Crop Protection Agents (CPAs) Used in the Production of Tobacco, continued

Trade Name (click for label)	SDS	EPA Registration No.	Type	Active Ingredient	Manufacturer	RUP[1]	Signal Word	Days PHI[2]	Hours REI[3]
Caravel	SDS	60063-58	herbicide	clomazone	Sipcam Agro	No	Warning	65 days	12 hrs
Carbaryl 4L - Drexel	SDS	19713-49	insecticide	carbaryl	Drexel Chemical Co	No	Caution	2 days	12 hrs
Carbaryl 4L - Loveland Products	SDS	34704-447	insecticide	carbaryl	Loveland Products	No	Caution	2 days	12 hrs
Civic 3ME	SDS	87290-55-89391	herbicide	clomazone	Innvictis Crop Care, LLC	No	Warning	65 days	12 hrs
Command 3ME	SDS	279-3158-5905	herbicide	clomazone	FMC Corp	No	Caution	Product not applied past 7 days after transplanting	12 hrs
Coragen	SDS	28982	insecticide	chlorantraniliprole	DuPont - Canada	No	Caution	1 days	4 hrs
Ceuva	SDS	67702-2-70051	fungicide	copper octanoate	Certis USA, LLC	No	Caution	No restriction stated on label	4 hrs
Devrinol 2-XT	SDS	70506-301	herbicide	napropamide	United Phosphorus, Inc	No	Caution	Not foliarly applied	24 hrs
Devrinol 50-DF	SDS	70506-36	herbicide	napropamide	United Phosphorus, Inc	No	Caution	Not foliarly applied	24 hrs
Devrinol DF-XT	SDS	70506-36	herbicide	napropamide	United Phosphorus, Inc	No	Caution	Not foliarly applied	24 hrs
Dipel DF	SDS	73049-39	insecticide	Bacillus thuringiensis	Valent USA	No	Caution	No restriction stated on label	4 hrs
Dipel ES	SDS	73049-17	insecticide	Bacillus thuringiensis	Valent USA	No	Caution	No restriction stated on label	4 hrs
Drexalin Plus	SDS	19713-510	sucker control	flumetralin	Drexel Chemical Co	No	Caution	No restriction stated on label	12 hrs
Durivo	SDS	100-1318	insecticide	thiamethoxam	Syngenta Crop Protection, LLC	No	Caution	Not foliarly applied	12 hrs
Endigo ZC	SDS	100-1276	insecticide	lambda-cyhalothrin + thiamethoxam	Syngenta Crop Protection, LLC	Yes	Warning	40 days	24 hrs
Exirel	SDS	352-859	insecticide	cyantraniliprole	Dupont	No	Warning	7 days	12 hrs
Fair 30	SDS	51873-9	sucker control	maleic hydrazide	Fair Products, Inc	No	Caution	7 days	12 hrs
Fair 80 SP	SDS	51873-17	sucker control	maleic hydrazide	Fair Products, Inc	No	Caution	7 days	12 hrs
Fair 85	SDS	51873-7	sucker control	C8-C10 fatty alcohol	Fair Products, Inc	No	Danger	No restriction stated on label	24 hrs
Fair Plus	SDS	51873-2	sucker control	maleic hydrazide	Fair Products, Inc	No	Caution	7 days	12 hrs
Fair-Tac C -10	SDS	51873-5	sucker control	C10 fatty alcohol	Fair Products, Inc	No	Danger	No restriction stated on label	
FluPro	SDS	400-600	sucker control	flumetralin	Arysta Lifescience North America, LLC	No	Caution	No restriction stated on label	12 hrs
Forum	SDS	241-427	fungicide	dimethomorph	BASF Ag Products	No	Caution	0 days	12 hrs
Framework 3.3 EC	SDS	1381-216	herbicide	pendimethalin	Windfield Solution	No	Caution	Not foliarly applied	24 hrs
FST-7	SDS	51873-6	sucker control	C10 fatty alcohol + maleic hydrazide	Fair Products, Inc	No	Danger	7 days	24 hrs
Fulfill 50WDG	SDS	100-912	insecticide	pymetrozine	Syngenta Crop Protection, LLC	No	Caution	14 days	12 hrs
Gramoxone SL 2.0	SDS	100-1431	herbicide	paraquat	Syngenta Crop Protection, LLC	Yes	Danger/Poison	Not foliarly applied to tobacco/when spray dries	24 hrs
Gramoxone SL 3.0	SDS	100-1652	herbicide	paraquat	Syngenta Crop Protection, LLC	Yes	Danger/Poison	Not foliarly applied to tobacco/when spray dries	24 hrs

[1] RUP: Restricted Use Pesticide
[2] PHI: Pre-Harvest Interval
[3] REI: Restricted-Entry Interval

table continued on next page

Crop Protection Agents (CPAs) Used in the Production of Tobacco, continued

Trade Name (click for label)	SDS	EPA Registration No.	Type	Active Ingredient	Manufacturer	RUP[1]	Signal Word	Days PHI[2]	Hours REI[3]
Gramoxone SL 3.0 Supplemental Label									
Harbour	SDS	66222-121	bactericide	streptomycin	ADAMA	No	Caution	No restriction stated on label	12 hrs
Helena Pendimethalin	SDS	241-337-5905	herbicide	pendimethalin	Helena Chemical Co	No	Caution	Not foliarly applied	24 hrs
Helm Sulfentrazone 4F	SDS	74530-63	herbicide	sulfentrazone	Helm Agro US, Inc	No	Caution	Not foliarly applied	12 hrs
HM-1512 AG	SDS	82534-5-5905	herbicide	sulfentrazone	Helena Chemical Co	No	Warning	Not foliarly applied	12 hrs
Instill	SDS	49538-5-92632	bactericide/ fungicide	copper sulfate pentahydrate	S.T. Biologicals, Inc	No	Warning	0 days	48 hrs
Javelin WG	SDS	70051-66	insecticide	Bacillus thuringiensis	Certis USA, LLC	No	Caution	No restriction stated on label	4 hrs
KOP-5	SDS	19713-695	algaecide/ bactericide/ fungicide	copper sulfate pentahydrate	Drexel Chemical Co	No	Warning	No restriction stated on label	24-48 hrs
K-PHITE 7LP	SDS	73806-1	fungicide/ bactericide	Mono- and dipotassium salts of phosporous acid	Plant Food Systems, Inc	No	Caution	0 days	4 hrs
Lannate LV	SDS	352-384	insecticide	methomyl	DuPont Crop Protection	Yes	Danger/Poison	14 days air or fire cured, 5 days flue cured	48 hrs
Lannate SP	SDS	352-342	insecticide	methomyl	DuPont Crop Protection	Yes	Danger/Poison	14 days air or fire cured, 5 days flue cured	48 hrs
Leven-38	SDS	19713-105	sucker control	C10 fatty alcohol + maleic hydrazide	Drexel Chemical Co	No	Caution	3 wk (21 days)	24 hrs
Lifegard WG	SDS	70051-119	fungicide	Bacillus mycoides	Certis USA, LLC	No	Caution	0 days	4 hrs
Lorsban 15G	SDS	62719-34	insecticide	chlorpyrifos	Dow AgroSciences	No	Caution	7 days	24 hrs
Lorsban-4E	SDS	62719-220	insecticide	chlorpyrifos	Dow AgroSciences	Yes	Warning	Not foliarly applied	24 hrs
Manzate Pro-Stick	SDS	70506-234	fungicide	mancozeb	United Phosphorus, Inc	No	Caution	30 days	24 hrs
Manzate Pro-Stick - Supplemental Label									
MetaStar 2E	SDS	71532-5-66330	fungicide	metalaxyl	LG Life Sciences	No	Warning	Not foliarly applied	48 hrs
Mocap 15% Granular	SDS	5481-9040	insecticide	ethoprop	Amvac Chemical Corporation	Yes	Danger/Poison	Not foliarly applied	48 hrs
Nordox	SDS	48142-1	fungicide	Cuprous Oxide	Nordox Industrier	No	Caution	No restriction stated on label	24 hrs
Nordox 75 WG	SDS	48142-4	fungicide	Cuprous Oxide	Nordox Industrier	no	Caution	No restriction stated on label	12 hrs
Nuprid 2SC	SDS	228-572	insecticide	imidacloprid	Nufarm Ag Products	No	Caution	14 days	12 hrs
Nuprid 4.6F Pro	SDS	228-527	insecticide	imidacloprid	Nufarm Ag Products	No	Caution	14 days	12 hrs
Nuprid 4F Max	SDS	228-528	insecticide	imidacloprid	Nufarm Ag Products	No	Caution	14 days	12 hrs
Off-Shoot-T	SDS	400-452	sucker control	C8-C10 fatty alcohol	Chemtura AgroSolutions	No	Danger	No restriction stated on label	24 hrs
Orondis Gold 200	SDS	100-1571	fungicide	oxathiapirolin	Syngenta Crop Protection, LLC	No	Caution	7 days	4 hrs
FIFRA Section 2(ee) Rcommendation									

[1] RUP: Restricted Use Pesticide
[2] PHI: Pre-Harvest Interval
[3] REI: Restricted-Entry Interval

table continued on next page

Crop Protection Agents (CPAs) Used in the Production of Tobacco, continued

Trade Name (click for label)	SDS	EPA Registration No.	Type	Active Ingredient	Manufacturer	RUP[1]	Signal Word	Days PHI[2]	Hours REI[3]
Orondis Ultra A	SDS	100-1572	fungicide	oxathiapirolin	Syngenta Crop Protection, LLC	No	Caution	7 days	4 hrs
Orondis Ultra B	SDS	100-1254	fungicide	mandipropamid	Syngenta Crop Protection, LLC	No	None	7 days	4 hrs
Orthene 75 SP	SDS	14225	insecticide	acephate	Arysta Lifescience North America, LLC	No	Caution	3 days	24 hrs
Orthene 97	SDS	59639-33	insecticide	acephate	Amvac Chemical Corporation	No	Caution	3 days	24 hrs
Penncozeb 75 DF	SDS	70506-185	fungicide	mancozeb	United Phosphorus, Inc	No	Caution	21 d in flue-cured tobacco	24 hrs
Pin-Dee 3.3 EC	SDS	19713-668	herbicide	pendimethalin	Drexel Chemical Co	No	Danger	Not foliarly applied	24 hrs
Platinum	SDS	100-939	insecticide	thiamethoxam	Syngenta Crop Protection, LLC	No	Caution	Not foliarly applied	12 hrs
Platinum 75 SG	SDS	100-1291	insecticide	thiamethoxam	Syngenta Crop Protection, LLC	No	Caution	Not foliarly applied	12 hrs
Plucker Plus	SDS	19713-649	sucker control	C8-C10 fatty alcohol + flumetralin	Drexel Chemical Co	No	Caution	No restriction stated on label	12 hrs
Poast	SDS	7969-58	herbicide	sethoxydim	BASF Ag Products	No	Warning	42 days	12 hrs
Presidio	SDS	59639-140	fungicide	fluopicolide	Valent USA	No	Warning	7 days	12 hrs
Prime+ EC	SDS	100-640	sucker control	flumetralin	Syngenta Crop Protection, LLC	No	Danger	No restriction stated on label	12 hrs
Prowl 3.3 EC	SDS	241-337	herbicide	pendimethalin	BASF Ag Products	No	Danger	Not foliarly applied	24 hrs
Prowl H2O	SDS	241-418	herbicide	pendimethalin	BASF Ag Products	No	Warning	Not foliarly applied	24 hrs
Quadris Flowable	SDS	100-1098	fungicide	azoxystrobin	Syngenta Crop Protection, LLC	No	Caution	0 days	4 hrs
Revus	SDS	100-1254	fungicide	mandipropamid	Syngenta Crop Protection, LLC	No	Caution	7 days	4 hrs
Ridomil Gold SL	SDS	100-1202	fungicide	mefenoxam	Syngenta Crop Protection, LLC	No	Warning	Not foliarly applied	48 hrs
Roundup PowerMax	SDS	524-549	herbicide	glyphosate	Monsanto	No	Caution	Not foliarly applied to tobacco	4 hrs
Royal MH-30	SDS	400-84	sucker control	maleic hydrazide	Arysta Lifescience North America, LLC	No	Caution	7 days	12 hrs
Royal MH-30 SG	SDS	400-165	sucker control	maleic hydrazide	Arysta Lifescience North America, LLC	No	Caution	7 days	12 hrs
Royal MH-30 Xtra	SDS	400-452	sucker control	maleic hydrazide	Arysta Lifescience North America, LLC	No	Caution	7 days	12 hrs
Royaltac	SDS	400-135	sucker control	C10 fatty alcohol	Arysta Lifescience North America, LLC	No	Danger	No restriction stated on label	24 hrs
Royaltac M	SDS	400-451	sucker control	C8-C10 fatty alcohol	Arysta Lifescience North America, LLC	No	Danger	No restriction stated on label	24 hrs
Satellite 3.3	SDS	70506-318	herbicide	pendimethalin	United Phosphorus Inc	No	Danger	Not foliarly applied	24 hrs
Satellite Flex	SDS	70506-324	herbicide	pendimethalin	United Phosphorus Inc	No	Danger	Not foliarly applied	24 hrs
Satellite HydroCap	SDS	70506-230	herbicide	pendimethalin	United Phosphorus Inc	No	Danger	Not foliarly applied	24 hrs
Sevin 4F	SDS	61842-38	insecticide	carbaryl	NovaSource	No	Caution	2 days	12 hrs
Sevin XLR Plus	SDS	61842-37	insecticide	carbaryl	NovaSource	No	Caution	2 days	12 hrs

[1] RUP: Restricted Use Pesticide
[2] PHI: Pre-Harvest Interval
[3] REI: Restricted-Entry Interval

table continued on next page

Crop Protection Agents (CPAs) Used in the Production of Tobacco, continued

Trade Name (click for label)	SDS	EPA Registration No.	Type	Active Ingredient	Manufacturer	RUP[1]	Signal Word	Days PHI[2]	Hours REI[3]
Shutdown	SDS	70506-326	herbicide	sulfentrazone	United Phosphorus Inc	No	Danger	Not foliarly applied	12 hrs
Spartan 4F	SDS	279-3220	herbicide	sulfentrazone	FMC Corp	No	Caution	Not foliarly applied	12 hrs
Spartan Charge	SDS	279-3337	herbicide	sulfentrazone + carfentrazone	FMC Corp	No	Caution	Not foliarly applied	12 hrs
Stealth	SDS	34704-868	herbicide	pendimethalin	Loveland Products	No	Caution	Not foliarly applied	24 hrs
Sucker Plucker	SDS	19713-35	sucker control	C8-C10 fatty alcohol	Drexel Chemical Co	No	Danger	7 days	24 hrs
Sucker Stuff	SDS	19713-1	sucker control	maleic hydrazide	Drexel Chemical Co	No	Caution	3 wk (21 days)	12 hrs
Sulfentrazone 4L	SDS	42750-357	herbicide	sulfentrazone	Albaugh, LLC/Agri Star	No	Warning	Not foliarly applied	12 hrs
Sulfin 4SC	SDS	82534-5-88783	herbicide	sulfentrazone	Summit Agro USA, LLC	No	Warning	Not foliarly applied	12 hrs
Super Sucker Stuff	SDS	19713-20	sucker control	maleic hydrazide	Drexel Chemical Co	No	Caution	3 wk (21 days)	12 hrs
Telone C-17	SDS	62719-12	soil fumigant	dichloroprpene + chloropicrin	Dow AgroSciences	Yes	Danger/Poison	Not foliarly applied	5 d (120 hrs) - see label
Telone II	SDS	62719-32	soil fumigant	dichloroprpene	Dow AgroSciences	Yes	Warning	Not foliarly applied	5 d (120 hrs) - see label
Terramaster 4 EC	SDS	400-422	fungicide	etridiazole	Chemtura AgroSolution	No	Danger	Not foliarly applied	12 hrs
Tide Acephate 90 WDG	SDS	84229-7	insecticide	acephate	Tide International USA, Inc	No	Caution	3 days	24 hrs
Tracer Naturalyte	SDS	62719-267	insecticide	spinosad	Dow AgroSciences	No	Caution	3 days	4 hrs
Ultra Flourish	SDS	55146-73	fungicide	mefenoxam	Nufarm Ag Products	No	Danger	Not foliarly applied	48 hrs
Up-Stage 3CS	SDS	70506-353	herbicide	clomazone	UPL NA Inc	No	Warning	65 days	12 hrs
Vapam HL	SDS	5481-468	soil fumigant	sodium methyldithiocarbamate	Amvac Chemical Corporation	Yes	Danger/Poison	Not foliarly applied	5 d (120 hrs) - see label
Verimark	SDS	279-9616	insecticide	cyazypry	Dupont	No	Caution	No restriction stated on label	4 hrs
Voliam Flexi	SDS	100-1319	insecticide	thiamethoxam + chloranitraniprole	Syngenta Crop Protection, LLC	No	Caution	14 days	12 hrs
Vopak 3ME	SDS	35915-25-66222	herbicide	clomazone	Adama USA	No	Warning	65 days	12 hrs
Warrior II with Zeon Technology	SDS	100-1295	insecticide	lambda-cyhalothrin	Syngenta Crop Protection, LLC	Yes	Warning	40 days	24 hrs
Widow	SDS	34704-893	insecticide	imidacloprid	Loveland Products	No	Caution	14 days	12 hrs
Willowood Clomazone 3ME	SDS	87290-55	herbicide	clomazone	Willowood USA	No	Caution	Product not applied past 7 days after transplanting	12 hrs
Willowood Imidacloprid 2SC	SDS	87290-33	insecticide	imidacloprid	Willowood USA	No	Caution	14 days	12 hrs
Willowood Imidacloprid 4SC	SDS	87290-26	insecticide	imidacloprid	Willowood USA	No	Caution	14 days	12 hrs
Willowood Sulfentrazone 4SC	SDS	87290-59	herbicide	sulfentrazone	Willowood USA	No	Warning	Not foliarly applied	12 hrs
XenTari	SDS	73049-40	insecticide	Bacillus thuringiensis	Valent USA	No	Caution	No restriction stated on label	12 hrs
Zone 4F	SDS	74530-63	herbicide	sulfentrazone	Helm Agro US, Inc	No	Warning	Not foliarly applied	12 hrs
Search for Other Pesticides									

[1] RUP: Restricted Use Pesticide
[2] PHI: Pre-Harvest Interval
[3] REI: Restricted-Entry Interval

Disclaimer: This is a listing of the most commonly used pesticides and is not a total listing of all pesticides registered for use on tobacco. Listing of certain products and omission of others does not constitute a recommendation or endorsement.

Revised 12-2020