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Burley and Dark Tobacco Production Guide

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Introduction

Bob Pearce, Andy Bailey, and Eric Walker

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 **G**ood **A**gricultural **P**ractices (GAP) program that was initiated during the 2013 growing season and expanded in 2014. Under 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. Training requirements may change, but growers are currently required to attend training every season in which they plan to sell tobacco. Additional information about U.S. Tobacco GAP can be found by contacting GAP Connections.

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 current research-based recommendations for the production of 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.

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Competing in a Global Marketplace

Will Snell

U.S. tobacco producers face a lot of challenges in today's marketing environment; consequently producers must attempt to gain any competitive advantage in combating the challenges from international competitors and an overall declining marketplace. Historically, U.S. tobacco producers competed primarily on price and quality. Because of its taste and aromas, U.S. tobacco has always been viewed as the best quality tobacco produced in the world. 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 blends.

Price, of course, remains a critical factor in determining purchasing decisions by tobacco companies. During the early years of the federal tobacco program, U.S. tobacco growers had pricing power, the quality advantage and limited foreign competition, but over the years of the tobacco program, U.S. policymakers had to adjust federal price supports and other policy variables to enhance the competitiveness of U.S. leaf in domestic and global markets. Today, without the support of a federal tobacco program, the level and variability of prices are determined by the tobacco manufacturers and dealers based on current supply and demand conditions. Given the increasing concentration in the number of buyers in today's global tobacco market place, tobacco companies have an enhanced degree of market power in establishing prices and controlling production practices.

In years with excess demand (as the U.S. burley sector experienced during much of the early post-buyout era), tobacco prices will be relatively higher with limited variation, and non-contract growers and auction markets can survive and often do particularly well regardless of leaf quality. Alternatively, in years when the global leaf supply is greater than demand, tobacco prices will tend to fall, be very volatile, and be vulnerable to lower quality leaf, especially lower quality leaf that is sold outside the contracting system.

Although price is still the single most critical factor in determining competitiveness, today's buying segment is looking more at "value," which 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 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 their products, and they are focusing on issues of their contract growers such as child labor and various environmental issues. In reality, today's tobacco product marketplace challenge is the ability to manufacture and deliver reduced-risk tobacco products to a declining consumer base amid a critical (and often times divided) public health community and government and global bodies calling for increased regulations. This situation 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. Although recordkeeping represents a cost in terms of time and labor, it may 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.

Most farmers value their independence and are reluctant to change. But this highly regulated tobacco product market will result in changes in the composition and types of tobacco products, which will require 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.

Required production changes in this volatile and competitive marketplace will force growers to closely monitor their changing cost structure and make critical investment decisions. In addition it becomes vital to improve communication flow from the company to the grower and from the grower to the company, outlining clear expectations and outcomes.

Surviving this new tobacco marketing environment will be a challenge. Intense international competition at much lower cost structures coupled with concentration in the buying sector will likely result in 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. Growers can achieve these desired results by adopting many of the recommendations in this production guide.

Selecting Burley Tobacco Varieties

Bob Pearce, Bob Miller, Eric Walker, 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 race 1 resistance, unless it is known that only race 0 is active in those areas.

Table 1. Survival of selected burley tobacco varieties in fields heavily infested with race 0 and race 1 black shank (2012-2014)

	Black Shank % Survival			
Variety	**2012**	**2013**	**2014**	**Mean**
KT 209LC	91	90	86	89
KT 210LC	83	86	92	87
KT 204LC	79	87	73	80
KT 206LC	70	75	74	73
HP 3307PLC	44	77	59	60
N 7371LC	39	64	53	52
TN 90LC	47	63	44	51
HB 4488PLC	44	58	36	46
NC 7LC	39	60	39	46
KT 212LC	31	46	46	41
HB 04PLC	18	18	14	17
Hybrid 404LC	14	5	14	11
KY 14 X L8LC	2	1	8	4
Seasonal Avg.	46	56	49	

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 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 Pest Management section 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.

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.

While there are some differences in varieties with regard to leaf quality, the differences are typically small (Figure 2, Table 2), with a range of only about 8 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 late fall as opposed to 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.

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 212LC is an early-maturing, high-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. It is the only commercially available variety with early maturity, high yield potential 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

Table 2. Performance of commercial varieties in the North Carolina official variety test at individual locations from 2010-2013

	Rocky Mount		Reidsville[a]		Laurel Springs[b]	
Variety	Yield lb/A	Quality Index	Yield lb/A	Quality Index	Yield lb/A	Quality Index
NC 5 LC	2277	69	2254	73	3233	75
NC 6 LC	2221	69	2190	72	3415	77
NC 7 LC	2249	69	2087	73	3297	76
KT 200 LC	2273	71	1974	71	3146	76
KT 204 LC	2168	68	2212	71	3384	75
KT 206 LC	2174	72	2011	70	3686	75
KT 209 LC	2162	70	2005	74	3518	75
KT 210 LC	2110	72	2149	74	3267	75
KT 212 LC[c]	2209	76	2066	66	--	--
TN 90 LC	2095	70	2195	72	2948	74
TN 97 LC	2084	69	2031	73	3382	75
HB 3307 LC	2198	69	2287	77	3294	74
HB 4488 LC[c]	2237	72	2280	68	--	--
R 610 LC	2234	73	2238	73	3246	77
R 630 LC	2162	73	2092	72	3122	76

[a] 2012 results not included.
[b] 2013 results not included.
[c] One year of results, varieties added in 2013.

Figure 1. Three-year (2011-2013) average yield (11 total location/years) of selected burley tobacco varieties grown in the absence of black shank pressure. Varieties are listed in order from highest to lowest yield.

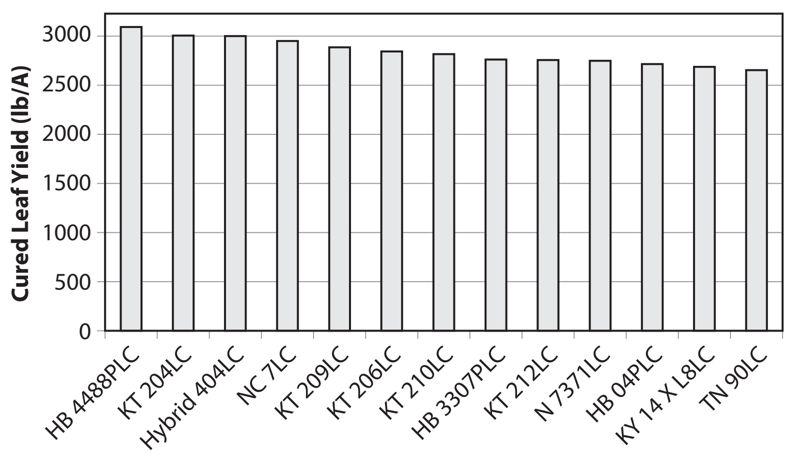
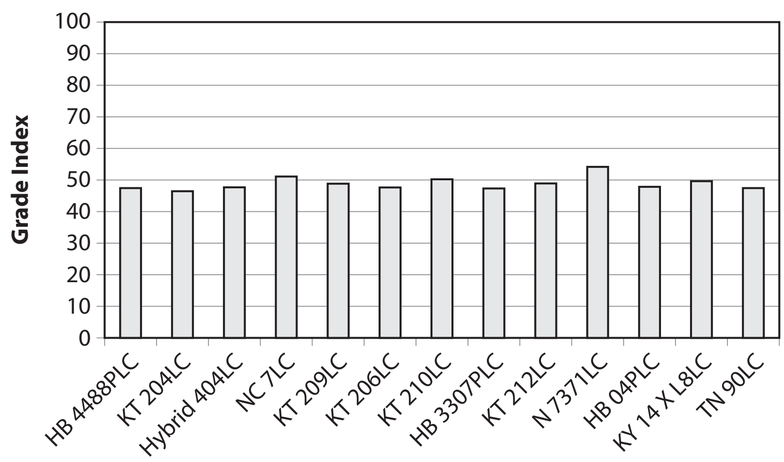


Figure 2. Three-year average (2011-2013) of grade index (9 total location/years) for selected burley tobacco varieties. Grade index is a numerical ranking of quality based on the federal grading system, a higher grade index indicates better quality.



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 Pest Management section). KT 210LC is 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 this KT 210LC. Cured leaf quality has been good.

Table 3. 2015 New and Selected[a] Burley Tobacco Varieties—Relative Disease Resistance, Yield Scores, and Maturity.

Variety	Black Shank RACE 0	Black Shank RACE 1	Virus Complex	Black Root Rot	Tmv	Fusarium Wilt	Relative Yield Score[b]	Maturity
ms KY 14 X L8LC	10	0	S	M	R	6	8	Early
KY 907LC	2	2	R	H	R	1	8	Med-Late
KT 200LC	6	6	R	H	R	0	8	Late
KT 204LC	7	7	R	H	R	1	9	Med-Late
KT 206LC[e]	10	7	R	H	R	1	9	Med-Late
KT 209LC	10	8	R	H	R	1	9	Med-Late
KT 210LC	10	7	S	H	R	5	8	Late
KT 212LC	10	4	S	H	R	5	8	Early
NC BH 129LC	1	1	S	H	R	1	7	Med-Early
NC 3LC[d]	2	2	R	H	R	1	7	Med-Late
NC 7LC[d]	10	4	R	H	R	5	8	Late
NC 2000LC[f]	0	0	S	L	R	1	4	Late
NC 2002LC[f]	0	0	R	M	R	0	5	Medium
TN 86LC	4	4	R	H	S	0	6	Late
TN 90LC[e]	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[c]	H[c]	R[c]	4	9	Medium
HYBRID 501LC	5	5	S	H	R	4	5	Med-Early
N 126LC	0	0	S	M	R	3	8	Medium
N 777LC	2	2	S	M	S	0	3	Med-Late
N 7371LC	4	4	-	-	-	5	7	Late
NBH 98LC	2	2	S	M	R	3	5	Medium
HB04PLC	0	0	S	H	R	0	9	Med-Early
HB3307PLC	10	4	R[c]	H[c]	S	3	8	Late
HB4488PLC	10	4	-	-	-	3	9	Late
R 610LC	4	4	S	M	-	3	5	Medium
R 630LC	3	3	R	M	R	4	5	Early
R7-12LC	0	0	S	H	R	4	8	Late

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

KT 209LC is a medium-late-maturing, high-yielding variety with superior black shank resistance. It has the highest available resistance to both races of black shank. 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 Pest Management section). 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 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 older 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 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, 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 mechanical harvest or 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 from F.W. Rickard Seed Inc. 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 Inc. 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 a stalk and plant size as some of the other new varieties.

HB4488PLC is a new variety from F.W. Rickard Seed Inc. It 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 from Clay's Seed Inc. 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, released by Newton Seed Inc., 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 2002LC is a medium-late maturing blue mold-resistant variety. It has very little resistance to other major diseases like black shank or black root rot. It is a higher yielding variety than NC 2000 but does not have the yield potential of high-yielding varieties like Hybrid 404, NC 7, HB 04PLC, or the "KT" varieties. It has very little disease resistance of any kind except to blue mold.

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 is a better choice due to higher race 1 resistance.

Choosing Dark Tobacco Varieties

Andy Bailey and Bob Miller

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	TMV[d]	Wildfire
		Race 0	Race 1						
NL Mad LC	Med-Late	0	0	F/A	7	9	None	None	None
TR Madole	Early-Med	0	0	F	6	6	None	None	None
Lit Crit	Med-Late	0	0	A/F	5	9	None	None	None
KY 160	Medium	0	0	A	3	9	None	High	None
KY 171[e]	Medium	0	0	A/F	7	7	High	High	None
DF 911	Medium	0	0	F	8	6	High	High	High
VA 309	Early-Med	2	2	A/F	6	7	Low	None	-
VA 359	Medium	1	1	A/F	6	7	Low	None	-
TN D950	Early	3	3	F	8	6	High	High	High
KT D6LC	Early-Med	3	3	F	8	7	High	High	High
KT D8LC	Medium	4	4	F/A	9	5	None	None	None
KT D14LC	Medium	10	5	F/A	8	7	High	High	High
DT 538 LC	Medium	4	4	F/A	8	6	High	-	-
DT 558LC	Medium	4	4	F/A	8	7	High	-	-
PD 7302LC[e]	Medium	10	0	F/A	6	7	High	High	-
PD 7305LC	Early	10	3	F	8	6	High	High	High
PD 7309LC	Medium	10	0	F/A	7	8	None	None	-
PD 7312LC	Medium	0	0	A/F	7	8	High	High	None
PD 7318LC	Medium	10	0	F/A	8	7	High	High	-
PD 7319LC	Medium	10	2	F/A	8	7	-	High	-

[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] Dash (-) means that resistance level is unknown or not rated at present.
[e] KY 171, PD 7302LC, and PD 7312LC have medium resistance to Fusarium wilt.

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 screened or 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 the Chemicals for Disease Management section 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 grass the year prior to tobacco is recommended. Dark tobacco should not be grown in the same field for two consecutive years.

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

Narrowleaf Madole LC is still one of the more popular dark tobacco varieties grown. It can be used as a fire-cured or air-cured variety and has medium-late maturity with good yield (3,200 lb/A) and cured leaf quality. It is known for its excellent curing characteristics. 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.

TR Madole is typically used as a fire-cured variety. 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.

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 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.

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.

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.

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 and low resistance to black root rot.

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

Table 2. Yield and quality grade index[a] for 2012-2013 dark fire-cured variety trials at Princeton and Murray, KY, and Springfield, TN[b]

	Princeton KY		Murray KY		Springfield TN		Average	
Variety	Yield (lb/A)	Quality Grade Index	Yield (lb/A)	Quality Grade Index	Yield (lb/A)	Quality Grade Index	Yield (lb/A)	Quality Grade Index
NL Madole LC	3747	71.9	3113	50.8	2819	65.0	3226	62.6
VA 309	3642	46.1	2755	57.0	2640	47.6	3012	50.2
TN D950	3993	59.5	3222	53.9	3001	59.5	3405	57.6
DT 538LC	4005	48.8	3238	57.8	3017	64.0	3420	56.9
DT 558LC	4092	63.3	3074	57.3	3031	62.9	3399	61.2
PD 7302LC	3781	53.8	2988	56.8	2710	65.0	3160	58.5
PD 7305LC	3924	60.5	3351	52.4	2815	62.8	3363	58.6
PD 7309LC	3786	57.0	3122	60.4	2660	57.6	3189	58.3
PD 7312LC	-	-	3111	72.2	3193	62.1	3152	67.2
PD 7318LC	4042	64.0	3084	57.5	3028	66.4	3385	62.6
PD 7319LC	3835	46.1	3219	63.8	2977	69.7	3343	59.9
KT D6LC	4240	59.9	3522	51.4	3118	58.4	3627	56.6
KT D8LC	4424	52.8	3444	43.0	3171	46.6	3680	47.5
KT D14LC	3963	57.5	3406	52.7	2896	59.9	3422	56.7

[a] Yield and quality grade index data averaged over 2012 and 2013 for Murray and Springfield. Princeton data from 2013 only. Quality grade index is a 0-100 numerical representation of federal grade received and is a weighted average of all stalk positions.

[b] Average yield across locations and varieties was 3051 lb/A in 2012 (Murray and Springfield only) and 3363 lb/A in 2013. Average quality grade index across locations and varieties was 57.5 in 2012 (Murray and Springfield only) and 58.1 in 2013.

Table 3. Yield and quality grade index[a] for 2012-2013 dark air-cured variety trials at Princeton and Murray, KY, and Springfield, TN[b]

	Princeton KY		Murray KY		Springfield TN		Average	
Variety	Yield (lb/A)	Quality Grade Index	Yield (lb/A)	Quality Grade Index	Yield (lb/A)	Quality Grade Index	Yield (lb/A)	Quality Grade Index
NL Madole LC	3364	42.3	2696	29.3	2542	31.8	2867	34.5
Lit Crittenden	3203	50.2	2786	26.4	2453	33.5	2814	36.7
KY 171	3456	43.1	2916	22.2	2561	30.6	2977	32.0
VA 359	3287	31.6	2592	17.7	2337	29.0	2738	26.1
DT 538LC	3493	18.6	2636	19.7	2528	28.9	2885	22.4
DT 558LC	3350	35.9	2983	19.0	2519	33.2	2951	29.4
PD 7302LC	3419	48.4	2770	22.1	2265	24.5	2818	31.7
PD 7309LC	3030	47.7	2710	25.6	2450	33.4	2730	35.6
PD 7312LC	4015	-	2782	-	2617	26.3	3138	26.3
PD 7318LC	3554	46.9	2833	21.8	2522	35.7	2970	34.8
PD 7319LC	3498	39.0	2647	22.1	2571	29.3	2905	30.1
KT D6LC	3900	29.0	3123	20.8	2687	28.9	3236	26.2
KT D8LC	3856	25.6	3060	15.7	2672	32.1	3196	24.5
KT D14LC	3783	21.1	3008	19.9	2575	28.8	3122	23.3

[a] Yield and quality grade index data averaged over 2012 and 2013 for each location. Quality grade index is a 0-100 numerical representation of federal grade received and is a weighted average of all stalk positions. Quality grade index data from Princeton and Murray is from 2013 only.

[b] Average yield across locations and varieties was 3113 lb/A in 2012 and 2768 lb/A in 2013. Average quality grade index across locations and varieties was 24.8 in 2012 (Springfield only) and 31.8 in 2013.

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.

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. 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.

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).

KT D14LC is the newest release from the University of Kentucky/University of Tennessee. It will perform relatively well as a fire-cured or air-cured variety. KT D14LC has the highest black shank resistance of any dark variety that has ever been released, with a level 10 resistance to race 0 black shank and a level 5 resistance to race 1 black shank. KT D14LC also has high resistance to black root rot, tobacco mosaic virus, and wildfire It has medium maturity with excellent yield characteristics similar to KT D6LC (3,400 lb/A) and should have slightly better leaf quality than KT D8LC, with leaf quality similar to KT D6LC.

DT 538LC was developed by Newton Seed Inc. and 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. DT 538LC has medium maturity with a semi-erect growth habit and fairly coarse leaf texture.

DT 558LC was developed by Newton Seed Inc. and was released as an LC variety in 2014. 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. DT 558LC has medium resistance to black shank race 0 and race 1 similar to DT 538LC.

PD 7302LC is a hybrid developed by F.W. Rickard Seed. 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 hybrid released by F. W. Rickard Seed in 2010. 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 is another hybrid developed by F. W. Rickard Seed. 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. It is a slightly more prostrate variety than PD 7302LC with excellent yield (3,400 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 developed by F. W. Rickard Seed Inc. 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 7312LC was temporarily discontinued in 2013 but is available again now.

PD 7318LC is a hybrid introduced in 2009 by F. W. Rickard Seed. PD 7318LC 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 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 a new hybrid released by F. W. Rickard Seed in 2013. PD 7319LC 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, low resistance to race 1 black shank, and is resistant to tobacco mosaic virus. Race 1 black shank resistance in PD 7319LC is slightly lower than in PD 7305LC. Yield characteristics of PD 7319LC should be similar to PD 7309LC and PD 7318LC (3,300 lb/A). Quality characteristics for PD 7319LC should also be similar to PD 7309LC and PD 7318LC. PD 7319LC is the first dark variety with high race 0 black shank resistance and at least low race 1 black shank resistance that has performed well as an air-cured variety.

Management of Tobacco Float Systems

Bob Pearce, Andy Bailey, David Reed, Steve Bost, Chuck Johnson, and Lee Townsend

The true value of a quality transplant lies in its potential to produce a high yielding plant at the end of the growing season. Poor field management can result in low yields from good quality transplants, but good field management cannot always rescue 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, 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, consider working with a local producer to minimize the risk of introducing diseases and to help stimulate the local farm economy

For growers who choose to produce their own transplants there are three general systems to consider: plug and transfer in unheated outdoor float beds, direct seeding in unheated outdoor float beds, and direct seeding in heated greenhouses. Each of these systems has its advantages and disadvantages, but all can be used to produce quality transplants. Table 1 shows a relative comparison of these three systems. Some growers may use more than one system; for example, seeding in a heated greenhouse and moving plants to an unheated bed after germination.

The U.S. 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, Sanitation, and Care

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.

Height and Cell Number

Trays may also differ in the height or depth of the tray. 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, the shallow trays had fewer dry cells, slightly lower germination, and slightly more spiral roots than regular trays (Table 2). 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.

Some float transplant producers try to maximize plant production per unit area as a means of lowering overhead production costs. Trays with a high cell number (338 and higher) have been used successfully by some greenhouse operators, but more time and a greater level of management are needed to grow transplants at these higher densities. Disease management is also more difficult with high cell numbers, requiring better environmental control, more frequent clipping, and diligent spray programs. For most tobacco producers with limited greenhouse experience, a 242- or 288-cell tray is a good compromise.

Trays with lower cell numbers are recommended for transplant production in outside beds. The lack of environmental control and infrequent clipping of outside beds makes the use of high density trays a risky venture. Since the cost of outdoor bed space is relatively inexpensive compared to a greenhouse, growers are under less pressure to produce the maximum number of plants per square foot.

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

Characteristic	Plug and Transfer	Direct Seed	
		Outside	Greenhouse
Labor requirement	High	Medium	Low
Cost per plant	Medium	Low	High
Target usable plants (%)	95	80	90
Management intensity	Medium	High	High
Risk of plant loss	Medium	High	Medium
Risk of introduced disease	High	Low	Low
Uniformity of plants	High	Low	Medium
Degree of grower control	Medium	Low	High
Time to usable plants (weeks)	3 to 4*	8 to 10	7 to 9

* Weeks after plugging

Table 2. 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.

Cleaning

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

Sanitization

A good sanitation program is critical for consistent success in the float system. For many of the diseases that are a problem 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.

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 spores of the disease organism 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 to 60 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 percent bleach solution, and covered with a tarp or plastic to keep them wet with the bleaching solution overnight. Because organic matter prevents bleach from reaching all the cavities of a tray, 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 also 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 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 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.

Storage

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 disinfected before storing them after harvest, or 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.

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.

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 severe enough to warrant switching to a different water source. For more information on water quality for float beds, see UK Cooperative Extension publication *Water Quality Guidelines for Tobacco Float Systems* (AGR-164).

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 provide 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 3). 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.

Table 3. Production of usable burley tobacco transplants in selected soilless media in a tobacco float system

	Usable Plants (%)		
Brand of Media	**2014**	**2013**	**2012**
The Gold	--	94.6	91.4
Carolina Choice	83.7	93.7	93.6
Premier Promix TA	--	93.2	90.7
Metromix Ag-lite	88.6	93.4	93.8
Southern States	87.2	--	91.4
Southern States w coir	85.0	--	--
Speedling fortified	86.1	--	89.7
Speedling Peat-Lite	84.4	91.6	89.7
Sunshine LT-5	87.2	91.8	91.5
Sunshine LT-3	85.9	91.9	--

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.

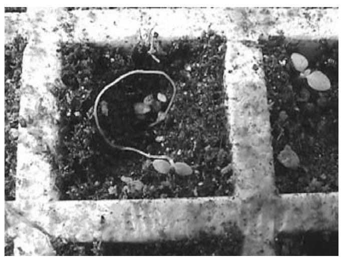
Often wicking can be seen within 5 to 10 minutes of floating trays. It should never take longer than 1 to 2 hours after floating for wicking to occur. For mild wicking problems where dry cells are slightly above normal, misting trays over the top for 10 minutes or so per 1000 square feet of float bed (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 percent, 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.

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.

Figure 1. Spiral root of a burley tobacco transplant.



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.

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.

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.

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 insure 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 seven 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.

Monitoring 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 easy it is to pass a current 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. 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.

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 in 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 (wall) 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 UK Cooperative Extension publication *Basics for Heating and Cooling Greenhouses for Tobacco Transplant Production* (ID-131).

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 favors the development of disease problems. High humidity can also 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 of 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 counterproductive 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.

Proper Procedures

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 percent 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 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

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 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, can't 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 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 damage seedlings or cause problems 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.

Gnats, Flies, Bloodworms, Mosquitoes, and Waterfleas

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.

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.

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.

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 very 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 causes serious problems in some greenhouse or float systems almost every year. 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.

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.

Tobacco Aphids/Green Peach Aphids

Tobacco aphids or 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.

Reducing aphid problems. Acephate (Orthene, etc.) can be used for aphid control in greenhouses and outdoor float systems. Catch infestations before they become too large to control effectively and direct sprays to the underside of the leaves.

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, but they also can carry tomato spotted wilt/impatiens necrotic spot virus.

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.

Reducing thrips problems. 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.

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.

Management of Diseases

The float system offers a number of advantages over the traditional plant bed for growing tobacco transplants but also creates ideal conditions for some important diseases. High moisture levels and high plant population 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, target spot, *Sclerotinia* collar rot, blue mold, 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. A list of recommended fungicides (Table 4) and relative effectiveness of cultural and chemical practices against common diseases (Table 5) have been included at the end of this section.

Develop an Integrated Plan

Disease-free transplants pay dividends over the course of the growing season because they are more vigorous and less prone 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.
- Control weeds in and around greenhouses and outdoor float beds. Weeds interfere with ventilation and also harbor pathogens and insects.
- Grow your own plants from seed if possible. If using plugs, grow your own or purchase from a local supplier. Don't buy

Table 4. Guide to chemicals available for control of tobacco diseases 2015—transplant production.

Product(s)	Product Rate Per Application[a]	Product Rate Per Season	Target Diseases	Label Notes
Agricultural Streptomycin (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	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 (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	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 4 EC	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 intervals. The curative rates can begin no sooner than 3 weeks after seeding. Apply no later than 5 days before transplanting.

[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.

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 as recommended 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. See "Tray Sanitation and Care" in this section for details.
- Clean and sanitize mowers and other equipment used in the float system frequently; a solution of 1 part bleach to 9 parts water is effective.
- 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 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 temperatures 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 blue mold and 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.

Minimize Plant Stress

Keep your transplants as stress-free as possible. Temperature extremes, too much or too little fertilizer, or improper clipping can cause undue stress on tobacco seedlings and increase the likelihood of disease. The following practices can help keep plants stress-free.

Table 5. Relative effectiveness of recommended practices for management of diseases of tobacco transplants

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	-	+	+++	+	+++	+++	+++	+++	+++	+++	-	-
Fungicidesb	+++	+++	++	++	-	++	+	++	+	+	-	+
Maintain proper fertilityc	+	++	+++	+	++	+	+++	+	+	+	-	+++
Temperature control	+	+	++	+	+	+	++	++	+	+	-	+
Minimize splashing	-	+	++	+	-	-	++	+++	+	++	-	-
Proper clippingd	-	-	++	+	++	+	++	++	+	+	-	-
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 under conditions that promote rapid drying of foliage.

- 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 disease susceptible. Over-fertilized plants also need to be clipped more frequently, increasing the risk to certain diseases.
- Clip properly (see "Clipping" in this section) to reduce plant stress, along with 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 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, 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. Older fungicides, such as Terramaster 35WP, Carbamate, Dithane and Ferbam can no longer be used on tobacco seedlings growing in float systems. Take care to avoid introduction of chemicals such as streptomycin and Aliette to float water to avoid plant injury. Following are guidelines for using fungicides against important diseases.

***Pythium* Root Rot**

- Preventive applications of Terramaster 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 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 re-treatment 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 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, but serious problems can be avoided by careful mixing and timely application. Terramaster will burn the roots of tobacco seedlings, but plants quickly recover. Stress from root burn is minimized if Terramaster 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 early.

Target Spot, *Rhizoctonia* Samping 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 VA) can be used for prevention of target spot and damping-off. Routine application is recommended for facilities with a history of target spot or damping-off. 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 fungicide is labeled for use on tobacco transplants 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.

Special Considerations for Outside Direct-Seeded Float Beds

Production of tobacco transplants in outside direct-seeded beds is inherently more risky than greenhouse production. Though the cost of transplants is lower in direct-seeded outside beds, the chances of plant loss are greater. Although results are related to the uncertainty of the weather, the risk of plant loss can be reduced by good preparation and management.

Construction of an outside float bed doesn't have to be complicated. However, a few details can make construction easier. A level spot is essential, because water will find the level. Having a deep end and a shallow end can result in fertilizers settling to the low end and, as water evaporates, trays may be stranded without water on the shallow end.

The float bed area must be free of debris that could potentially punch a hole in the plastic liner. Sand spread evenly within the bed area provides a good foundation.

Bed framing made from 2-by-6's or 2-by-8's is sufficient to construct a float bed. Most float trays are slightly smaller than 14 by 27 inches. Float tray dimensions can be used to calculate the dimensions needed for the float bed, but allow for a very small amount of extra space in case trays are slightly larger than expected. Cover any extra space that must be left, as open water will only lead to increased algae growth and potential insect problems.

Six-millimeter plastic is more forgiving and preferred over thinner plastic. The plastic should be draped over the frame and pushed into corners before filling with water. The addition of water to the bed will complete the forming of the plastic to the sides, and only then should the plastic be tacked to the frames. Stapling through plastic strapping materials makes a more secure attachment of the plastic lining to the frames. The bed should be no wider than can be covered by a conventional cover stretched over bows. Bows should be 2 to 4 ft apart and can be constructed of metal or PVC pipe but need to be strong enough to support the wet weight of the cover. Bows spaced wider apart will need to be stronger than those spaced closer together. Allowing some head space over the plant aids ventilation.

Covering materials are most commonly made from either spun-bonded polypropylene (Reemay covers) or spun-bonded polyethylene (Continental covers). Both provide some protection from the cold and rain. However, temperatures inside the beds can fall below outside temperatures during the night. The most plausible explanation is that evaporative cooling inside the bed is responsible for the drop in temperature. Outside beds may not be suitable for seeding much earlier than the middle of April unless supplemental heat is used. Heat can be obtained from 150-watt light bulbs placed at each bow or every other bow, depending on the degree of heat need anticipated. If any electrical appliances or equipment are used near the float bed, a ground fault interrupt (GFI) should be installed at the outlet or in line.

Plastic covers can help reduce rain damage to freshly seeded trays and trays where plants have not covered the cell. However, failure to remove the plastic when the sun comes out can damage seeds and kill plants very quickly. A clear cover heats up inside quickly, and a black plastic cover left on for an extended period of time during rainy weather can cause plants to stretch due to lack of light. Once plants stretch, they will not recover. Greenhouse grown plants are more susceptible to rapid changes in temperature and should have at least two days to acclimate in an outside bed prior to a cold snap. Newly plugged plants are also susceptible to wind damage, which can desiccate plants. Normal plant bed covers are usually sufficient to protect plants. Once new roots become established (two days is usually sufficient), wind is less of a problem.

Field Selection and Soil Preparation

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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, potential herbicide carryover, 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 the reason 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.

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 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 are yellowed 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), if certain brassicas are allowed to go to seed, they can become a nuisance weed in the following cash crop.

Crop rotation. The benefit of crop rotation for reducing certain diseases is well known (see Disease Management section); 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 tillage and 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 Grazon, Surmount, Milestone, and Forefront. Tobacco should not be planted in fields which have had aminopyralid applied in the previous two years. For picloram, the period of time needed before planting tobacco is longer than two years, but 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 that 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 U.S., the level of tillage used for tobacco is intense. Tillage in tobacco production is useful to help control weeds, incorporate cover crops, reduce 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 uncompacted soil, the pores make up about 50 percent 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 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 to 25 percent or near field capacity. Field capacity is the soil moisture content when free water drainage ceases and occurs about two days after a "normal" rain.

Naturally occurring compacted zones, known as fragipans, are also found in some soils, more commonly in Western Kentucky and Western Tennessee. 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 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 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 approach 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 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,

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.

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 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 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.

Other factors should be considered prior to cultivating. Two common soil-borne diseases in tobacco are black shank and Fusarium wilt (discussed in the Disease Management section). 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 showed that cultivation was not necessary to produce good burley tobacco yields when adequate weed control was achieved with preplant herbicides (Table 2).

Throughout the burley and dark tobacco growing regions, tobacco is grown on sloping fields, much of it on slopes of 6 percent 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 sight 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.

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

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

Soil Type	Compaction	Cured Leaf Yield (lb/A) Conventional	Cured Leaf Yield (lb/A) Sub-soiled
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.

Table 2. Cured leaf yield at Spindletop (ST) and Woodford County (WC), KY for 2008, 2009, and 2010 †

Treatment	Cured Leaf Yield (lb/A) ST 2008	ST 2009	ST 2010	WC 2010
No Cultivation, not weeded	2493	3094	2863	1927
No Cultivation, hand-weeded	2623	---	2774	---
Early Cultivation	---‡	2937	---	2061
Late Cultivation (at layby)	2539	3009	2935	2024
Early and Late Cultivation	---	3082	---	2165
Three Cultivations	2340	---	---	---

† No statistical differences were observed between treatments for any year or location.
‡ No data collected.

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.

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. In addition, 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 percent of the residue on the surface; and strip-till, in which a 10- to 12-inch-wide band is tilled before transplanting. Each system has 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). Tobacco can be grown no-till 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 3). On a moderately well-drained silt loam soil with a fragipan at the Springfield Research and Education Center, no-till yielded significantly less than strip-till and conventional tillage.

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 initial burndown should be made with a product containing glyphosate. A follow-up treatment with a paraquat-containing product may

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

Table 3. Burley Yields by Tillage System, Greeneville and Springfield, TN 2009.

Tillage System	Cured Leaf Yield (lb/A) Greeneville	Springfield
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.

be made within a few days of transplanting when residual weed control products are applied.

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 section of the 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. However, many glyphosate-containing products have a statement on the label that allows the products to be used 30 to 35 days prior to planting of crops not specifically listed on the label. Be sure to check the label of the specific product that will be used. Some products containing paraquat (Gramoxone SL 2.0) have been labeled specifically 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 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.

Spartan 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 options. Either Prowl or Command can be tank-mixed with Spartan for improved control of certain weeds and grasses. However, the most consistent control has been achieved by applying Spartan seven to 10 days prior to transplanting and then making an application of Command within seven days after transplanting. The post-transplant application of Command 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* section for labeled rates of herbicides.)

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.

Fertilization

Edwin Ritchey, Bob Pearce, 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 six 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 G.A.P. 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 insure 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 insure the pH at midseason 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 the effects of leaching, plant growth, and repeated applications of acidifying forms of nitrogen. 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 and fully neutralize soil acidity.

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 pel-

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 on-line 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
VA	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
PA		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

letized limestone is typically higher than ag-lime, the reaction time is similar. There are two factors that 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 typically 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 four to six weeks after transplanting. The stunting in severe cases of Mn toxicity can reduce leaf yields by as much as 400 pounds per acre. By the time symptoms have been observed much of the damage has already been done; however, if caught early enough, a rescue treatment of 1000 pounds. 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 pounds 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 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.

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 better 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 pounds N per acre with no SD actually resulted in maximum yield, but in three of the trials, during wetter than average seasons, the crop did respond to an additional 50 pounds of N side dressed. At no time did the crop respond to side dress applications when 240 pounds of N was applied as a pre-plant application. 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 contribute to higher levels of tobacco specific nitrosamines (TSNAs), which are discussed in more detail in a later section of this guide.

Phosphorus and Potassium

Phosphorus (P) and potassium (K) are relatively stable in soils, so fertilizer additions should be determined primarily 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.

Spring applications of chloride-containing fertilizers, such as muriate of potash (0-0-60) at rates greater than 50 pounds of chloride per acre, lead to excessive levels of chloride in cured burley tobacco leaf. High chloride levels lead to increased curing and storage problems, decreased combustibility of the leaf, and ultimately, greatly reduced quality and usability of the cured leaf. Some tobacco buying company contracts specifically limit the amount of muriate of potash that can be applied during a growing season. Consequently, sulfate of potash (0-0-50) should be the major potassium fertilizer used on tobacco fields after January 1 of the current crop year. Recent shortages of sulfate of potash mean growers must consider other alternatives such a 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 and limit the uptake of Cl. 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 percent chloride in cured leaf. Consult your local cooperative extension office to see if fall applications of muriate of potash are recommended in your area.

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 (lb/A)	Pre-plant Nitrogen (lb/A)		
	80	**160**	**240**
	Cured Leaf Yield (lb/A)		
	2358	2520	**2643**
	2527	**2660**	**2659**
	2648*	**2647**	**2652**

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

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. Sulfur deficiencies have not been reported for tobacco within the regions where burley and dark tobacco are grown.

Micronutrients

Only two micronutrients are routinely recommended for burley or dark tobacco production. Molybdenum (Mo) is recommended for use on burley tobacco in Kentucky when the soil pH is below 6.6. Research and 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 dry solid or a liquid. Either source is satisfactory when molybdenum is needed.

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 because only one trip over the field is necessary. It is recommended that not more than 2 pounds 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 pound sodium molybdate (1.6 to 3.2 oz of molybdenum) per acre. If dry sodium molybdate is used, divide the total recommended amount (0.25 to 0.50 lb/A) equally among the number of barrels of water used per acre. For example, if two barrels of water per acre are used, add one-half of the total recommended amount to each barrel and fill the barrel with water. Adding the dry material before filling the barrel will aid in dissolving and mixing. If a 2.5 percent liquid source of molybdenum is used with two barrels of setter water per acre, add 1 to 2 quarts of the liquid product per barrel before filling the barrel with water.

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 to 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 midrib 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, in burley. 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 pH where boron deficiency is suspected, a broadcast application of 1 pound of boron per acre may be warranted. 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 pounds B delivered in 300 gallons of transplant water per acre was enough to cause B toxicity symptoms in the 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 crops 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 insure that chloride levels are acceptable and to 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 those nutrients the grower does not realize any of that added value in additional cured leaf.

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 manures should not be applied in the spring where tobacco will be grown. Fall applications of poultry litter should not exceed four 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.

Topping and Sucker Control Management

Andy Bailey, David Reed, Loren Fisher, Scott Whitley, and Bob Pearce

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, both in the removal of 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 important, 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 percent bloom (when 10 to 25 percent of the plants in a field have at least one open flower) generally provides the best yield and quality. 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 percent bloom may be similar or better than tobacco topped at 10 to 25 percent bloom if harvested at three weeks after topping, whereas tobacco topped at 10 to 25 percent 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 and KT 210 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 or KT212 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 increases 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 percent bloom will be counterproductive. A balance must be found between extra labor required to produce those leaves, 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 percent 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, second, and leaf grades that are desired by the industry. Lower topping to 12 to 14 leaves does make tobacco easier to handle on the stick during housing and may cure better in older barns with narrow tier spacing but also results in mostly lug and leaf with little or no true seconds. 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.

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,** which are not absorbed by plants and must have direct contact with suckers and leaf axils, where they physically burn tender suckers
- **Local systemics,** which 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,** which do not have to come into direct contact with suckers but 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.

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.

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 on contact and suckers that are shorter than one inch; 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 one 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 percent solution is suggested on labels for contact chemicals. General recommendations are 3 to 4 percent solution for burley tobacco and 4 to 5 percent 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 gallons of contact chemical in 50 gallons of total spray solution per acre (3 to 5% solution). For stalk-rundown applications with backpack or hand sprayers, a 3 to 5 percent solution is 12 to 19 fluid ounces of contact chemical per 3 gallons 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.

Local systemics

Butralin, Prime+, Flupro, and Drexalin Plus are the local systemic products currently available. Butralin and flumetralin 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 one inch should be removed prior to application. Local systemics do not burn suckers like contacts but rather stop sucker growth; suckers remain 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 gallon per acre 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 fluid ounce 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 quarts of local systemic per acre when tank-mixing with contacts and 2 quarts per acre 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 gallon per acre per application. In North Carolina only, Prime+ may be applied twice per season at up to 0.5 gallon per acre per application.

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 pounds of MH per gallon (Royal MH-30, Super Sucker-Stuff, Fair Plus), a higher concentrate liquid containing 2.25 pounds of MH per gallon (Royal MH-30 Xtra, Sucker-Stuff, Fair 30), and a dry formulation (Royal MH-30 SG, Sucker Stuff 80EG, Fair 80SP) that contains 60 percent MH by weight. Regardless of the MH formulation, the recommended rate if used alone should be equivalent to 2.25 to 3 pounds of active ingredient (MH) per acre and 1.5 to 2.25 pounds 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.

Table 1. MH product formulations currently available

MH Product		Concentration of MH (lb/G for liquid or % for dry products)
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 Weight (lb/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	5.2	2548	56.6	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).

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 chapter unless otherwise noted. Regular-concentrate MH used alone can be applied at a rate of 1.5 to 2 gallons per acre. Recommended use rate for high-concentrate MH is 1 gallon per acre, which is equivalent to 1.5 gallon per acre of the regular concentrate. All MH formulations should be applied at a spray volume of 50 gallon per acre.

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. Optimum time to apply MH is on overcast or hazy days or in the morning after dew dries on hot, clear days. 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.

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 gallon per acre of regular concentrate MH in combination with 2 quarts per acre of a local systemic applied with coarse nozzles. The combination with 1.5 gallon per acre MH consistently controls suckers as well as the full 2 gallon per acre 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 3). 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 gallon per acre rate (regular concentrate) will reduce residues and has often provided sucker control that

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

Year	MH rate lb ai/A (gal/A)	Parts Per Million MH residue on cured leaves (average of all stalk positions)				
		TN[1]	VA	NC-LS	NC-R	KY
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 lb ai/A = 2 gallons per acre regular concentrate; 2.25 lb ai/A = 1.5 gallons per acre regular concentrate; 1.5 lb 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

Year	Sucker Control Treatment applied in 50 G/A as a coarse spray	% Sucker Control	Cured Leaf Yield (lb/A)
2011	Check Topped No Sucker Control	0.0	2434
	MH 3.00 lb ai/A (2.0 gal/A)	98.9	2813
	MH 2.25 lb ai/A (1.5 gal/A)	99.0	2904
	MH 2.25 lb ai/A (1.5 gal/A) + 1% FluPro (0.5 gal/A)	99.2	2826
	MH 1.50 lb ai /A (1.0 gal/A) + 1% Flupro (0.5 gal/A)	98.9	2733
2012	Check Topped No Sucker Control	0.0	2559
	MH 3.00 lb ai/A (2.0 gal/A)	95.0	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

was equivalent to the 1.5 gallon per acre rate in research trials (Tables 2, 3, and 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.

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 gallon per acre. 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 gallon per acre 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 all sucker control products.

Plucker Plus is a 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 gallon per acre. Up to two applications of Plucker Plus can be made per season, at 1.25 to 2.5 gallon per acre per application. Plucker Plus must be applied in a manner to achieve stalk run down of the material.

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 gallons per acre spray volume, and coverage may improve on many crops as spray volume is increased to 60 or 70 gallons per acre. 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; 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 three-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 three-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 in recent years comparing sucker control and MH residue with conveyor hoods and standard three-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 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 miles per hour range. For flatter ground where speed can be increased to 4 to 5 miles per hour, 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 fluid ounces of spray solution to each plant, taking care 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 gallon per acre 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. Refer to Appendix I (Pest Management section) 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 fluid ounces 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 3 gallon 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.

Refer to Appendix I in the Pest Management section for PPE requirements.

Jug Applications

Jug applications involve adding the chemical to a gallon jug with water and pouring 0.5 to 0.75 fluid ounces 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 6 for conversion of product rates from gallons of product per 50 gallons of spray solution to ounces of product per gallon of spray solution.

Refer to Appendix I in the Pest Management section for PPE requirements.

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 gallon per acre MH (regular 1.5 lb/gal formulation) with 2 quart per acre of a local systemic as an over-the-top application with powered spray equipment. Top tobacco at 10 to 25 percent bloom, and remove all suckers longer than one inch. Spray applications can be made within one day before or after topping. If upper leaves will be less than eight inches long at topping, apply a contact at topping and then follow with 1 to 1.5 gallon per acre MH (regular 1.5 lb/gal formulation) plus 2 quarts per acre 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 percent bloom can have suckers near the top of the plant that are more than one 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 gallon per acre of MH (regular 1.5 lb/gal formulation) and 2 quarts per acre 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 gallon per acre MH (1.5 lb/gal formulation) plus 2 quarts per acre 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 with a contact or 1 gallon per acre 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 gallon per acre MH (1.5 lb/gal formulation) over the top using powered spray equipment.

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 be required 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 gallon per acre 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.

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 percent 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 percent solution (2 to 2.5 gal/50 gal total solution) with a local systemic at 3 quarts per 50 gallons or a local systemic alone at 1 gallon per 50 gallons. 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 nor have upper leaves less than eight inches long, direct the application below these smaller leaves. Another strategy is to apply a local systemic at 1 gallon per acre alone or at 0.75 gallon per acre 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 gallon per acre 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 percent solution at the first topping and again seven days later. Follow with a local systemic at 1 gallon per acre 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 5).

Table 5. 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 Weight (lb/10 plants)	Total Dark-Fired Yield (lb/A)
OST (2 gal/A)	-	-	12	45.7	2080
	OST (2.5 gal/A)	OST (2 gal/A) + Butralin (0.75 gal/A)	74	27.9	2834
		RMH (1 gal/A) + Butralin (0.75 gal/A)	88	13.7	2854
		RMH (1.25 gal/A) + Butralin (0.5 gal/A)	92	14.6	2920
		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.

Table 6. 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
1.0	2.6
1.25	3.2
1.5	3.8
1.75	4.5
2.0	5.1
2.25	5.8
2.5	6.4
2.75	7.0
3.0	7.7

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 quarts per acre (1.25 to 1.5 gal/A of the regular 1.5 lb/gal formulation) is recommended. Rates lower than 5 quarts per acre will provide marginal sucker control, and rates higher than 6 quarts per acre 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 quarts per acre regular concentrate MH alone or tank-mixed with 2 quarts per acre of a local systemic (Table 5). 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 eight-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 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 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 when 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 of 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 six 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 four 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.

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 condition 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 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 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 flexible 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 not cut 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. 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 eight to nine 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 not currently recommended.

Facilities and Curing

John Wilhoit, Andy Bailey, and Larry Swetnam

Conventional Barn Renovation and Remodeling

Curing facilities continue to be a limiting factor for producers wanting to expand their production. With the high cost of new barns, the renovation and remodeling of existing barns can be an economic advantage. Many curing barns remain that are generally in good structural condition. With some remodeling, they can often be improved to make housing easier and/or to aid the curing process. Following are a few possibilities.

- Good burley curing requires lots of natural air. Be sure ventilator doors or equivalent openings equal one-fourth to one-third of the barn side wall area and are positioned to permit natural air to enter and go through the hanging tobacco. Keep the vent doors in good repair so they can be opened and closed as required to regulate ventilation and manage the cure. Whenever possible, remove such obstructions as trees, bushes, and hay stacked in attached sheds that block prevailing winds.
- Install full-width driveway doors to accommodate wagon access and increase housing efficiency. An amazing number of people 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 big, green tobacco; aid curing of tightly housed tobacco in humid weather; and aid air movement in barns with poor ventilation. See *Using Fans in Conventional Burley Barns* (AEN-69) on the selection, installation, and use of fans in tobacco barns.
- Many producers have found that in older 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 practice eliminates overlapping and produces better air movement. Sticks can usually be placed closer together when the plants do not overlap, thus compensating in barn capacity for the omitted tiers. The tier rails should not be overloaded; the tiers may break, and air movement through the tobacco may be reduced.

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

Considerations for What Type of Tobacco Barn or Curing Facility You Should Build

There are several options for new tobacco barn construction as well as field curing structures. Plan to build the most suitable facility for present and future production methods. With labor becoming more scarce and costly, 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. Trends toward mechanization affect whether a facility can 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 they 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.

Barns (fixed-roof structures)

When planning new fixed-roof curing facilities, producers should consider these 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, which can save over half of the housing labor
- Structures that permit other possible farm uses during the non-curing season, such as machinery and supply storage
- Future modifications for different tobacco housing and curing methods or other farm enterprises that may change significantly in the future

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 serious consideration if curing capacity expansion is needed. They require considerably less labor for hanging because they are only one tier high, and they are safer because workers do not have to climb to multiple tier heights. Curing quality has generally been found to be as good or better in outside curing structures as in traditional barns, and tobacco in outside curing structures can be in case more readily than tobacco in traditional barns. However, there are other challenges with using outside field curing structures.

- Additional labor and expense related to covering the structures with plastic negate some of the advantage in labor efficiency over traditional barns.
- The plastic cover and the tobacco are subject to increased damage from strong winds and other weather.
- The space requirements for outside field curing structures are substantial, generally about one-quarter acre (including space for maneuvering) for every 1 acre of curing capacity.
- Maintenance issues are associated with outside field curing structures (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 can be more difficult to secure the plastic cover to.

Designs and Plans

More than three dozen designs and plans and various publications related to curing facilities are currently available on the UK Biosystems and Agricultural Engineering website at http://www.bae.uky.edu/ext/tobacco. General groupings include:

- 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
- 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 free-standing, especially layouts for the new big-bale operations

Facility Design and Location

A barn should be located in an open, well-drained area with the broad side facing the direction of the prevailing wind to provide the best cross ventilation. The best location is on a high point on the farmstead. 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 amount of tobacco the air must pass through. Traditionally, barns have been 32, 40, or 48 feet wide and as long as needed to hold the desired amount of tobacco. However, more and more 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, as it can be difficult to get sufficient air movement for proper curing in the center of such large barns. In particular, 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 for improved curing, although not operating fans during drier weather can reduce air exchange and maintain better humidity conditions.

For fire-curing barns, a major consideration on overall barn size is 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 to allow subsequent firing practices to be the same throughout the entire barn. For this reason, many fire-curing barns hold no more than 3 to 4 acres even on larger operations.

Lumber of sound quality and proper strength should be used for construction as shown in typical plans. For labor saving in housing, the sheds 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 side wall area. Some air-curing barns are being built with metal siding without adequate side wall ventilation. Inadequate ventilation will result in houseburn during humid weather or with tightly spaced tobacco. Air-cured tobacco should never be housed and cured in a fire-curing barn.

Lower cost plastic-covered field structures can use untreated wood or preservative-treated wood, which will last longer. 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, so it is important to build them strong. Contrary to barns, field structures should be located in more protected areas, as they tend to have ample air movement through the tobacco but are subject to damage from strong winds. Locate field structures beside barns or downwind from fencerows or tree lines to help protect them from the wind.

Costs and Labor Efficiency

Curing facility initial costs can range from $900 to $1,500 per acre of capacity for simple field curing structures with plastic covers to $6,000 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 $150 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 cost per pound can be higher due to interest paid if a short-term construction loan is necessary.

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 the tobacco leaf's chemical and physical properties 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 percent. The study was based on airflow of 15 feet per minute (⅙ mph velocity) through the tobacco in the 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." The changes in varieties, fertility, and cultural practices of the last couple of decades as well as buyer preferences have resulted in a darker brown to red, thicker leaf now being favored. Recent barn and chamber studies have indicated that steady or daily average relative humidity in the 72 to 75 percent range produces the quality of tobacco leaves currently desired by the industry, thus a higher daily average humidity than that of the historic study.

During late August through September, the recommended tobacco air-curing season in Kentucky, the outdoor temperature seldom goes above 90°F or below 60°F for any great length of time. Relative humidity can dwell near 100 percent during heavy dew or foggy nights and briefly may drop below 40 to 50 percent in the heat of the day, thus averaging around 70 to 75 percent. The cooler October temperatures can often go below 60°F for an entire day and/or several consecutive evening periods, with humidity ranging from 25 to 30 percent in daytime to not over 70 to 80 percent in evening hours, resulting in daily averages of 45 to 55 percent. 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. The chemical conversions are too slow because of the 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 results in a 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 houseburning weather. Houseburn results in a dark leaf with excessive loss in dry weight. The excessive weight loss is primarily caused by the action of microorganisms that cause soft rot.

Temperature determines the undesirable colors that prevail in the cured leaf during improper curing; however, the relative humidity (if airflow is adequate) 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 mainly 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 controlled primarily by operating the ventilators, plastic covering, or other air control means to regulate the ventilation rates.

The 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. 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 for $25 to $39 each. Hang these up 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 the past cycle of conditions and reset as desired. The accuracy of relative humidity measurement is generally plus or minus 3 percent, which is reasonable for the price.

A new electronic, interactive tobacco curing advisory tool has been developed in a collaborative effort by the Department of Biosystems and Agricultural Engineering and the Kentucky Agriculture Weather Center at the University of Kentucky. The curing advisory uses real-time data from the Kentucky Mesonet system, now in 65 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 the 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 use of 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 90°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
- 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, and ventilators should be managed carefully to prevent houseburn and sweating. Firing should begin when yellowing is nearly complete (yellow spots appear or the majority of the leaf lamina has reached a solid yellow color). This condition usually occurs between five and 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 in an attempt 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.

Initial fires during yellowing and color-setting phases 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 also result in excessive temperatures and increased levels of NOx gases that may contribute to increased TSNA formation (see TSNA chapter).

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 price 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. In recent years, growers have been forced to use a finer sawdust produced from band saws. Band sawdust may also have much less uniform particle size than the coarser circular sawdust. The finer band saw dust 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 saw dust may also have a tendency to allow burning on top of the sawdust. The finer band saw dust 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 it only contributes to more caking and more tunneling of the fire underneath the sawdust. Wetting piles of band sawdust for one to two days prior to loading in the barn is recommended. Growers using the finer band saw dust should use extra caution when firing, and those supplying sawdust to growers should be aware that circular sawdust is much preferred.

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 six to seven weeks to fire-cure a crop of dark tobacco by conventional means. This time frame can still be applied to 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 five weeks. 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 to 15. Second cures should be transplanted June 5 to 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. 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 in order 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 in order to stay on the five-week schedule. Artificial moisture will almost certainly have to be used to take down 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. 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 either 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).

Using Fans in Conventional 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 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 per minute of 0.1 inch static pressure-rated airflow for every two bents of 32 to 40-feet wide barn. This requirement 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 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. Timers 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 500 to 600 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, for baling equipment, and for removing the bare stalks
- Doorways large enough to accommodate tobacco handling 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 Biosystems and Agricultural Engineering website show typical construction of traditional stripping rooms. More than 20 possible layouts of larger stripping rooms for the big baler operation are also shown on the site (http://www.bae.uky.edu/publications/EXT/Tobacco/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.

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.

Leaflet 293, *Improving Light Conditions for Stripping Tobacco* (http://www.bae.uky.edu/publications/EXT/Tobacco/Lf293.pdf) on the BAE website describes various details of lighting and color features for stripping rooms. Other details of space, doorways, heating, and construction can be obtained from the blueprint plans.

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 and chemicals stored in shop areas that double as stripping rooms and market preparation areas.

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Stripping and Preparation of Tobacco for Market

Andy Bailey, Eric Walker, Larry Swetnam, and John Wilhoit

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. 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 percent or higher relative humidity for several hours (four to 12, 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 (see Information on steamers and humidifiers for tobacco conditioning on the BAE website at http://www.bae.uky.edu/ext/Tobacco/tobacco_cond.htm).

Tobacco in equilibrium with air below approximately 60 to 65 percent 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 percent 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. The development of a way to efficiently reduce the moisture content of large batches of loose tobacco too wet to bale could be a benefit to growers as well.

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 the tobacco easier to handle 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 time period.

Bulking of notched plants from non-stick curing structures should be done according to the techniques above depending on whether the stalks are still green and moist or more dried and brown.

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, prepare to strip the bulk promptly, open up 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 to 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.

An "ordering room" with heat and humidifiers available and adequate sealing to control humidity can be useful. 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 flying may not be produced. Growing conditions, agronomic practices, and variety may also limit the amount 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. As a result, 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 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. But the mixed middle grade will be a problem for all buyers, perhaps reducing market quality grades from 1's or 2's to 3's and causing the mixed middle grade to 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 Kentucky and Tennessee 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, or 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 the Update on Burley Harvest and Stripping Mechanization section for further information about stalk choppers.)

With the predominance of big baling and the non-oriented leaf packaging that it allows (see Baling section), 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 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 that 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 a 30 to 40 percent. 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 that 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 than 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.

Burley Baling

The small conventional bale of oriented leaves with air cylinder compression in wooden boxes (an industry standard since the 1980s) has now largely 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 percent 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 requires 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 requested 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 percent 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 is supposed to take bale density into account. There is a probe that was designed and manufactured a number of years ago for measuring the moisture content in smaller bales of burley tobacco called the Tobacco Chek moisture meter (Dagmar Enterprises LLC, Leawood, KS). The Tobacco Chek moisture probe operates on the same principle as hay moisture testers but has been specifically calibrated for measuring and displaying tobacco moisture. 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 three to four locations to determine the average moisture for the bale. In evaluations conducted by the University of Kentucky with a cooperating grower on approximately 100 big bales, the average of three probes readings per bale were generally similar to 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 Tobacco Chek 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 percent 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 be unobtainable 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 or that have dark green areas resulting from sunburn or other weather-related damage in the field. Many marketing contracts will only support lug, second, and leaf grades and will not support trash and green. Some marketing contracts for dark-fired tobacco will require stripping into only two grades (lug and leaf), or even one grade, excluding trash and green. Three grades are usually required by most contracts for dark air-cured tobacco. Target moisture levels at delivery are generally no more than 25 percent for dark fire-cured and 22 percent for dark air-cured. Refer to marketing contracts for specific stripping, grading, and marketing specifications.

Marketing Packages for Dark Tobacco

Baskets

All marketing packages used for dark tobacco involve at least some level of leaf orientation, as there are currently no options for tangled leaf marketing packages as with burley. The basic unit of many dark tobacco marketing packages is 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" 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 introduced by some companies in recent years.

Boxes

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. A larger, wood-reinforced cardboard box known as a "v-hog" has recently been introduced by at least one dark tobacco buying company. The v-hog box is much larger than C-48 boxes and can contain approximately the same amount of tobacco as a basket, with a target weight of 850 pounds but not exceeding 900 pounds. Dimensions of this large box are 42 inches wide x 44 inches tall x 44 inches long. An advantage of this large box over baskets is that they can be stacked for transport much more easily than baskets.

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 percent 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 larger 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. Remember that NTRM is not just synthetic articles such as plastic drink cups and food wrappers but also includes non-marketable plant material such as stalk pieces, suckers, and weeds. Stripping crews should be monitored frequently to insure that the stripping area and marketing packages are free of NTRM.

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Burley Harvest and Stripping Mechanization

John Wilhoit and Larry Swetnam

Burley tobacco production is labor intensive; the biggest part of the labor requirements are harvesting and stripping. Considerable effort has been put into mechanizing harvesting and stripping operations over the years, but as long as labor remained available at reasonably low rates, it has been less costly to manually harvest and strip the tobacco. Accordingly, adoption of new mechanization concepts and devices by producers has been sporadic and short-lived. However, increasing difficulties with the availability of labor may spark renewed interest in mechanization.

Harvesting

The automated burley harvesters manufactured by GCH International were used to harvest large amounts of tobacco on farms in both Illinois and Kentucky from 2006 to 2009. These machines can drastically reduce the labor requirements for harvesting tobacco, but the system is very expensive, and only one of the units originally manufactured is still in use in the United States. That unit has been used to harvest approximately 80 acres annually on a farm in Henry County, Kentucky. Meanwhile, a tobacco growers' cooperative in France purchased a new unit of the harvester from GCH and used it to harvest approximately 60 acres in 2011. Subsequently, they purchased a second unit and used both to harvest approximately 165 acres in 2012 (Wells et al., 2012). The quality of the cured leaf using the automated harvester system has been judged to be equivalent or superior to that from conventional harvesting in France, and efforts are continuing there to reduce system cost and improve reliability.

Three-point hitch mounted plant-notching harvesters manufactured by MarCo Manufacturing Company and Kirpy generated considerable interest from growers following their demonstrations at field days in 2005 through 2007, and many of them were purchased and used by growers in Kentucky, North Carolina, and Indiana. In the past few years, however, growers have ceased switching over to this harvesting technology, and many growers who own the machines have even quit using them. There are many reasons for the waning interest in the notching harvesters. While they do speed up harvesting operations considerably, the harvest labor savings are largely offset by the very high labor requirements for hanging the single-notched plants on wire, compared to hanging sticks of tobacco. Also, use of the machines imposes some constraints on managing harvest labor, as the wagons filled with fresh-cut loose plants cannot be left for long periods to wilt as stick-cut tobacco can be left in the field, and large labor crews may not be able to work largely unsupervised as they can with traditional stick harvesting operations. Another severe limitation is the difficulties these and other harvesting machines have with handling wind-blown, crooked tobacco stalks, as are concerns about excessive losses due to leaf breakage (Wilhoit and Duncan, 2012).

A new low-cost harvesting concept that mechanizes tobacco hanging operations has been under development and evaluation for several years in the Department of Biosystems and Agricultural Engineering at the University of Kentucky. With this concept, traditional stick-harvested tobacco is loaded onto loose wooden rails carried through the field on a rail wagon, then these rails are picked up from the rail wagons and set in place on field curing structures using a large set of forks on a tractor front-end loader. The loads of approximately 50 sticks each can be transported efficiently to field structures using the tractor with front-end loader provided the distance to the structure is not too far (approximately 600 ft or less). Initial work with this system focused on the use of portable wooden field structures that can be set up close to the tobacco field in order to minimize this travel distance. Use of portable field curing structures in this manner can help encourage better rotation practices, but it adds a lot of difficulty and expense to the use of the system. To overcome some of the limitations of using portable field structures, trials were conducted in 2014 evaluating the use of larger unit loads transported longer distances by tractor to permanent field curing structures. With this configuration of the system, the loader tractor stays at the structure, while multiple transport units (tractors pulling trains of rail wagons) cycle between the tobacco field and the field curing structures. The results of these trials with the larger unit load configuration were encouraging. A benefit of this configuration is that it can be adapted to increasingly larger scale operations by adding additional tractor/rail wagon trains. As with other outside field curing structure systems, the wooden rail harvesting system eliminates hazardous hanging work high off the ground and significantly reduces hanging labor requirements compared to hanging in traditional tobacco barns.

Stripping and Market Preparation

A mechanical leaf-removing stripping machine developed by Carolina Tobacco Services 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 have to 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 was able to strip around 70 pounds per worker-hour, or about 35 worker-hours per acre for a 2,500-pound-per-acre crop (compared to 50 to 75 worker-hr/A for conventional stripping) (Wilhoit and Duncan, 2013). Very few of these machines were ever purchased by private growers, however, as the high initial cost and high maintenance costs of the machines are hard to justify despite the potential savings in stripping labor. Other factors have also limited the adoption of this technology. The distribution of leaf into grades is less precise than with hand stripping, due to differences in the length of stalks and the fact that some lower stalk leaves will fall off the stalk prematurely as it goes through the machine and be in the upper stalk boxes. It is very difficult to properly separate flyings from cutters due to differences in stalk length. This limitation results in mixed grades and has led to lower prices in some cases for the mechanically stripped tobacco. Suckers, morning glory vines, and pieces of stalk also end up in the tobacco, potentially increasing NTRM problems.

Other stripping concepts are under development and evaluation in the Department of Biosystems and Agricultural Engineering at the University of Kentucky. One concept uses string trimmers to detach different leaf grades as stalks are conveyed along a length in a configuration similar to that of the CTS stripping machine but with the stalks held upright from below and the flyings stripped by hand as the machine is loaded, rather than held from above and the tips stripped by hand. Lab-scale tests with a prototype based on this concept have given promising results with stripping efficiencies, but challenges/limitations have been encountered in attempting to scale the prototype up to continuously strip large numbers of plants. Grading accuracy and string wear/breakage are issues with this concept that need to be evaluated on an operational scale (Sperry et al., 2013). Another very high capacity mechanical stripping system has been under development 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).

Another mechanized stripping machine system that has been used for a number of years by French tobacco growers has recently received some interest in the United States. The machine, which is called Tabworks, is made by the Spanish company Eodiss Systems (http://www.eodiss.com/es/agricola/contactar.html). With this machine, tobacco stalks are placed across a chain conveyor with the leaves hanging downward, and the machine uses a pair of opposing rollers to pull the leaves from the stalk (separated by stalk positions into different grades) as the stalks are conveyed past. Some efforts to determine the applicability and labor efficiency of using this machine with U.S. burley have recently been initiated.

The changeover to big bale packaging for burley production and the accompanying opportunity for putting non-oriented leaf into the bales, led to an initial flurry of interest in various stripping aids that moved the stalks past the workers allowing them to use both hands to more rapidly remove the leaves. Such aids include the stripping wheel and various types of straight-line conveyors. Of these stripping aids, the dual chain conveyor, which moves sticks of tobacco hanging vertically downward past the workers, has gained the most widespread use, especially in dark tobacco. In one study, the dual chain conveyor had a reported labor productivity of 57 pounds per worker-hour for 10.8 workers, meaning an overall capacity of over 600 pounds per hour, quite high for a relatively simple and inexpensive mechanism (Wilhoit and Duncan, 2013). As the size of tobacco operations has increased since the end of the federal quota system, timeliness in getting a crop processed has become more important, meaning high capacity can be a more critical factor for producers than actual labor efficiency when it comes to mechanization innovations.

Some of the initial interest in these stripping aids seems to have leveled off as growers have tried different ways of incorporating big balers into their stripping system to improve labor efficiency. Some of the things growers are doing include pulling wagonloads of tobacco directly into large stripping rooms, taking portable balers to the barns and stripping wagons in the barn driveway, using various multi-chambered balers that have become available, powering two balers off a single hydraulic power source, and even stripping directly into the balers. Some growers consider stripping aids to fit well into their systems, while others may feel that they are obtaining good efficiency with whatever setup they are using for organizing the workers and relaying the tobacco stalks.

There continues to be interest in using stalk choppers with the larger-scale stripping operations that are becoming more common, although the uncertainties in the tobacco markets have probably curtailed interest somewhat. Many farmers have converted old forage choppers, powering them electrically, to make tobacco stalk choppers. Several units of a purpose-built tobacco stalk chopper developed in the Department of Biosystems and Agricultural Engineering at the University of Kentucky have also been used on Kentucky farms in the last several years. Two units of this stalk chopper were built and sold by a local fabricator, but no one is manufacturing the unit at this time. Stalk choppers that incorporate conveyers, so that they are fed continuously as workers strip the tobacco, offer the best gains in efficiency for stripping operations because they eliminate the need for accumulating bare stalks and carrying them out of the stripping room and manually loading them on wagons or in manure spreaders. Chopping the stalks can have significant advantages on the loading and spreading end as well, especially if the chopped stalk is loaded directly into manure spreaders. Labor requirements for spreading are considerably reduced compared to having to throw whole stalks off a wagon manually, and uniformity is much better than if whole stalks are spread with a manure spreader.

Videos of the operation of some of the mechanization innovations mentioned, as well as information about the sources of some of the equipment, are shown on the UK BAE tobacco website: http://www.bae.uky.edu/ext/tobacco. Check the BAE website for periodic updates.

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TSNAs in Burley and Dark Tobacco

Anne Jack, 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 precursor 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 selecting screened or LC seed results in significantly lower TSNAs.

The amount of nitrosating agent. Nitrite, NO^{2-}, 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 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.

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 U.S., 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.

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

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 indirect; nitrate is 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 produced 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.

Figure 1. NNN formation.

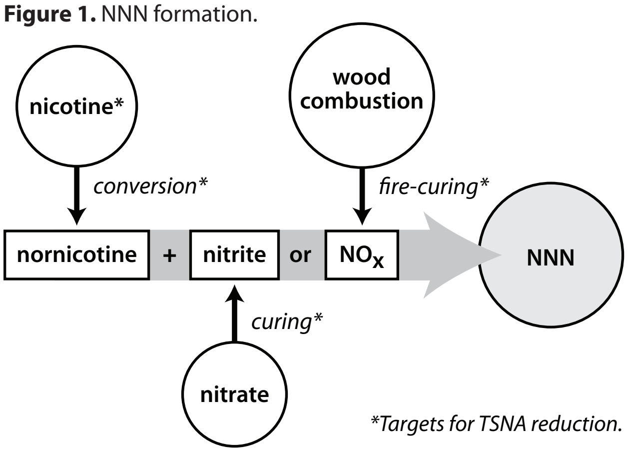


Figure 2. NNN (ppm) for high converter (HC) and low converter (LC) burley varieties over two years. Within each year, bars with different letters are significantly different at the 5% level.

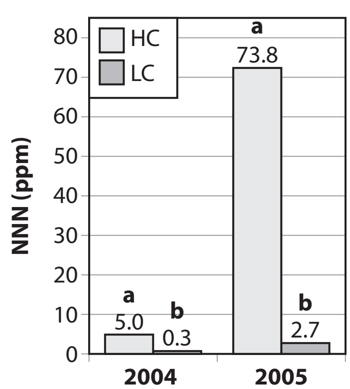
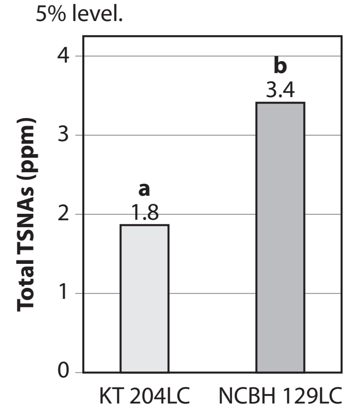


Figure 3. Total TSNAs (ppm) for KT 204LC and NCBH 129LC; mean over two years. Bars with different letters are significantly different at the 5% level.



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) and by the use of muriate of potash fertilizers.

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. In addition to 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.
- Avoid spring applications of muriate fertilizers. If muriate fertilizers are used, they should be applied in the fall. Chloride also has an adverse effect on quality and causes the cured leaf to be more hygroscopic (moisture absorbing).

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 converters.

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 section of this publication).

Maturity at Harvest

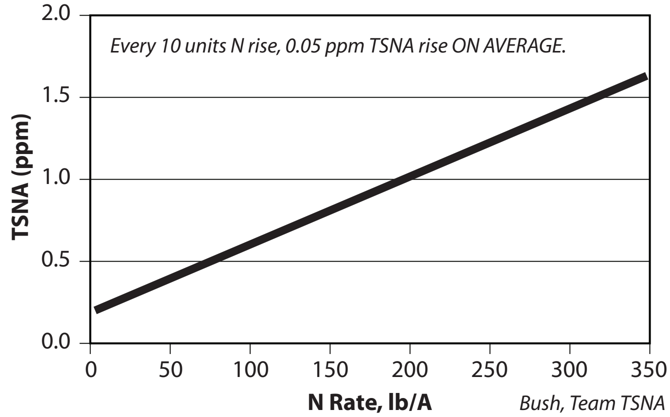
Several studies have shown that TSNAs increase with increased maturity at harvest. Earlier studies used unscreened seed, and we know that conversion increases with increased maturity. Current results show a similar but smaller response with the low converter varieties now in use. The increase in TSNAs 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 five to six weeks after topping; some early maturing varieties may require earlier harvest.
- **Dark fire-cured.** Harvest six to seven weeks after topping; some early maturing varieties may require earlier harvest.

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



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.

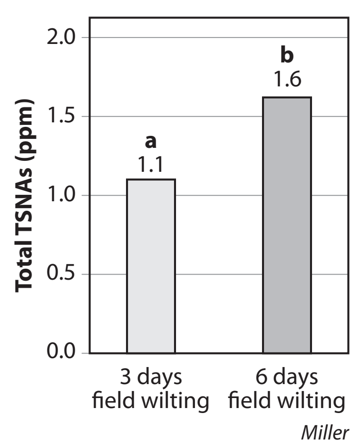
Air-Curing

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 site, 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

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



remains alive and active longer during curing, allowing more conversion of nicotine to nornicotine. Thus, with the increased nitrite and nornicotine available, more TSNA is 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.

Tests have shown that TSNAs in outdoor burley curing structures are very similar to those in a conventional barn (Figure 6) 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 be manipulated to a limited extent to maintain quality. 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.

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 ventilators, 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. 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.

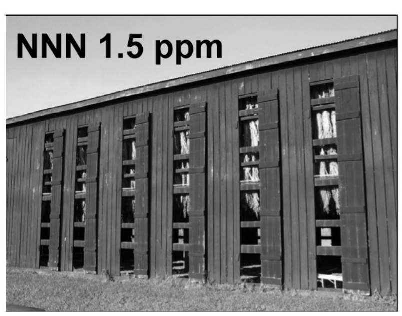
Ideally, start firing within seven days after housing. Avoid firing the tobacco more or longer than necessary to produce cured leaf with acceptable quality and marketability. Growers should strive to keep barn temperatures below 130°F, even during the drying stage of the cure. Ideally, tobacco should not be kept at 130°F longer than four to five days; by seven days at this temperature, TSNAs would be expected to increase.

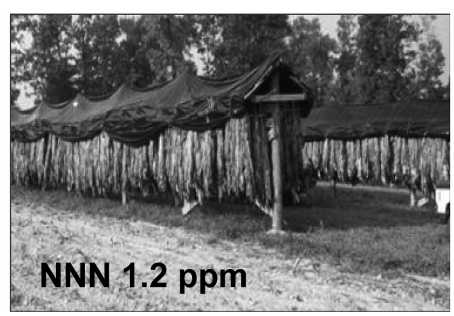
Artificial casing with overhead misting systems or steamers is often required for takedown in dark fire-cured tobacco due to the extremely dry condition of the tobacco after curing is complete. This is particularly true with first cures in double-crop curing, where takedown needs to occur quickly following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

What the grower can do

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.

Figure 6. NNN (ppm) in a conventional barn (left) and outdoor curing structure (right).





- 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.

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 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, sometimes resulting 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.
- Avoid spring applications of muriate fertilizers.
- 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.
- 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.

Weed Management

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

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 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 burn-down 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 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 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	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	G	G	G	G	G	G	P	N	N	N	P	N	G	P	G	P	G	P	N	F	F
Spartan	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.

Table 2. Herbicides recommended for use in tobacco fields

Herbicide	Weeds Controlled	Remarks and Limitations
Before Transplanting—Burndown Herbicides for Use in Conservation Tillage		
Gramoxone SL 2.0 2.74 to 3.75 pt/A (*paraquat* 0.6 to 0.94 lb ai/A) + Non-Ionic Surfactant 2 pt/100 gal or Crop Oil Concentrate 1 gal/100 gal *Supplemental label for use in KY, TN, and NC only*	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.*** 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		
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)	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.
Prowl 3.3EC 3 to 3.6 pt/A (*pendimethalin* 1.25 to 1.5 lb ai/A) or **Prowl H_2O** 3 pt/A (*pendimethalin* 1.4 lb ai/A)	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 PROWL is used. Wheat or barley may be planted 120 days after application unless small grains will be planted in a no-tillage system. Similar pendimethalin products include ACUMEN, FRAMEWORK 3.3EC, PENDIMETHALIN, and STEALTH.
Command 3ME 2 to 2.67 pt/A (*clomazone* 0.75 to 1 lb ai/A)	Barnyardgrass, broadleaf signalgrass, crabgrass, fall panicum, foxtails, jimsonweed, lambsquarters, prickly sida, purslane, common ragweed, velvetleaf	Apply COMMAND 3ME as a soil-applied treatment prior to transplanting. Off-site movement of spray drift or vapors of COMMAND 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 may be tank-mixed with other herbicides registered for use in tobacco to broaden the weed control spectrum or with other tobacco pesticides. 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 COMMAND 3ME is 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.
Spartan 4F 8 to 12 fl.oz/A (*sulfentrazone* 0.25 to 0.375 lb ai/A)	Black nightshade, jimsonweed, lambsquarters, morningglories, pigweeds, prickly sida, purslane, smartweed	Use the higher rate of SPARTAN 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. 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 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.

continued

Table 2. (continued)

Herbicide	Weeds Controlled	Remarks and Limitations
Spartan Charge 10.2 to 15.2 fl.oz/A (*carfentrazone* 0.028 to 0.042 lb ai/A + *sulfentrazone* 0.25 to 0.38 lb ai/A)	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.
At Transplanting—Soil-Applied Herbicides		
Command 3ME 2.0-2.67 pt/A (*clomazone* 0.75-1.0 lb ai/A)	Barnyardgrass, broadleaf signalgrass, crabgrass, fall panicum, foxtails, jimsonweed, lambsquarters, prickly sida, purslane, common ragweed, velvetleaf	Apply COMMAND 3ME as a soil-applied treatment over-the-top of tobacco plants immediately or up to 7 days after transplanting but prior to emergence of weeds. Off-site movement of spray drift or vapors of COMMAND 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 may be tank-mixed with other herbicides registered for use in tobacco to broaden the weed control spectrum or with other tobacco pesticides. 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 COMMAND 3ME is 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) *For use in Kentucky, Maryland, Virginia and Southeast Region only*	Barnyardgrass, broadleaf signalgrass, crabgrass, fall panicum, foxtails, purslane	May be applied over the top of transplants. Apply to a weed-free soil surface immediately after transplanting. If rainfall does not occur within 5 days after application, the treatment must be shallowly incorporated or irrigated-in. DEVRINOL may also be applied as a directed layby application to the row middles. (Consult label). Small grains 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 other crops not specified on the label, do not plant rotational crops until 12 months after the last DEVRINOL application.
After Transplanting—Postemergence Herbicides		
Poast 1.5E 1.5 pt/A (*sethoxydim* 0.28 lb ai/A) + oil concentrate 2 pt/A	Barnyardgrass, broadleaf signalgrass, crabgrass, fall panicum, foxtails, johnsongrass,	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). 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/A) 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.

Disease Management

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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 (of which few are available for tobacco), yield losses can occur and quality of the crop can be affected. 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 have to be carried out or in place before disease appears, which requires planning ahead. 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. Where preventive programs aren't 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. You can also access information online that can help with identification of disease problems. Websites provided by the University of Tennessee (http://tobaccoinfo.utk.edu) feature up-to-date information on tobacco diseases and recommended controls as well as advisories on current disease problems (such as blue mold).

Avoid 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 can be an effective way to manage black shank, Fusarium wilt, and black root rot. Locating fields away from areas with large, unmanaged populations of weeds can help minimize problems with a number of insect-transmitted plant viruses, such as alfalfa mosaic and tomato spotted wilt. In areas with a history of problems with aphid-transmitted viruses, planting tobacco early will ensure that the crop is older and less susceptible when aphid populations begin to increase. However, early plantings may suffer from black root rot when a susceptible variety is planted. On the other hand, planting later to avoid early season thrips activity may reduce losses to tomato spotted wilt.

Rotate with non-related crops. Crop rotation is a highly effective tool for preventing and managing diseases, particularly those caused by soilborne pathogens (including nematodes) or that result from carry-over in crop debris. Regular rotation away from tobacco and related crops deprives pathogens of their preferred source of food, 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 one- to two-year period in tobacco should provide good control of soilborne diseases for most growers. Do not follow tobacco with tobacco if black shank, black root rot, or Fusarium wilt are observed in a field. Although less than ideal, short rotational intervals can reduce disease pressure in fields after a serious disease outbreak; however, longer intervals between susceptible crops, as discussed earlier, are more effective. Unfortunately, crop rotation is not effective against all diseases. Diseases caused by pathogens that don't overwinter in soil or on plant debris, such as 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 and problems with black shank. 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 such as target spot and blue mold. 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.

Exclude plant pathogens from the field. Keep plant pathogens out of "clean" fields by sanitizing equipment and shoes, and by limiting animals' access to fields, especially if you share equipment or farm in several different areas. This practice can help reduce the introduction and spread of pathogens that cause black shank and Fusarium wilt. To avoid introduction of 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 in Kentucky, Tennessee, Virginia, or North Carolina, or north of that region. Plants produced south of that region may have been exposed to blue mold at their source, and their importation into the region 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 blue mold and black root rot; however, low nitrogen levels can contribute to severe outbreaks of target spot, so be sure to use recommended amounts of nitrogen fertilizers for optimal crop production.

Go to the field with healthy transplants. Don't set plants with severe 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—destroy them immediately. Such plants will die, or if they survive, they will not thrive and will serve as a source of spores for an outbreak 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 to be a problem. Using resistant varieties is one of the least expensive management practices—the cost is built into the price of the seed. 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 sections on selection of burley and dark tobacco varieties.) 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.

Correctly use fungicides. 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 (Table 1). Pay attention to safety precautions, 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 in order to suppress infection must be in place before the arrival of the pathogen. Applications made after a disease has become established will take longer to bring the epidemic under control or, worse, may not be successful at all. Maintain recommended application intervals while disease threatens or the weather favors disease. Applying fungicides with a specific mode of action (such as Quadris or Forum) when high levels of disease are present could lead to the development of resistance in certain plant pathogens—yet another reason to think preventively when using fungicides.
- **Use an application volume that gives the best coverage of plants.** For most fungicides, this amount will change as the crop grows. In general, use 20 gallons per acre near transplanting, increasing to 40 gallons per acre when plants are knee-high, 60 gallons per acre when plants are waist-high, 80 gallons per acre when plants are chest-high, and as much as 100 gallons per acre for applications made at topping or afterward. Spray pressure should be between 40 and 100 psi and use hollow-cone nozzles for best effect. 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.
- **Calibrate sprayers for accurate delivery.** This practice will ensure that the crop receives neither too little fungicide (poor disease control) nor too much (extra cost and potential injury). Clean nozzles regularly 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 are more durable and less prone to wear.

Harvest in a timely manner and correctly manage barns. Overmature 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. These bacterial diseases are occasionally important and do not cause significant losses in most years. 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. Refer to earlier chapters for a listing of dark tobacco varieties with good resistance to wildfire. Use of chemicals to manage these diseases is rarely necessary; however, agricultural streptomycin (Table 1) can be applied preventively at 100 ppm (8 oz/100 gal) or after symptoms first appear at 200 ppm (16 oz/100 gal). Continue applications while conditions favor disease development (typically warm and wet weather).

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 for managing black shank. 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 significantly reduce disease; however, rotations of three to five years have the greatest impact on black shank. A number of crops serve as good rotation partners with tobacco. Legumes and vegetables may promote the buildup of other soilborne pathogens responsible for diseases like black root rot.

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 runoff from infested fields. Steps should be taken to minimize soil saturation, since these conditions favor infection by *P. nicotianae*. Eliminate areas in fields were water stands, or install tiles to improve drainage. Keep in

Table 1. Guide to chemicals available for control of tobacco diseases in the field, 2015—foliar applications

Chemical	Product Rate Per Application[a]	Product Rate Per Season	PHI[b] (days)	Target Diseases	Label Notes
Agricultural Streptomycin, Agri-Mycin 17, Harbour	100-200 ppm (4-8 oz/50 gal H_2O)	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	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 on a 10-day schedule. Apply in a minimum of 20 gal/A.
Mancozeb (Manzate Pro-Stick, Penncozeb DF)	1.5-2 lb	no limit	30	blue mold, anthracnose	Some buyers have expressed concern over residues of mancozeb on tobacco. Consequently, use this product only as needed— as a tank-mix with Forum or in alternation with Quadris. Only Manzate ProStick is labeled in most burley states, while only Penncozeb DF is labeled in VA.
Aliette WDG	2.5-4 lb	20 lb	3	blue mold	Make first application immediately after transplanting; continue on a 7-10 day schedule. Use a minimum spray volume of 20 gal/A; increase by 20 gal/A weekly to a maximum of 100 gal/A.
Forum (formerly Acrobat)	2-8 fl oz	30 fl oz	0	blue mold	Increase rate and application volume (20-100 gal/A) as crop size increases. According to the product label, Forum must be tank-mixed with a product registered for control of blue mold, 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.
Quadris 2.08SC	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, 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; however, minimize post-topping application, as fungicide residues are a significant industry concern. Do not mix with EC-type pesticides or with sucker control materials.
Revus 2.08SC	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.

[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.

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 and good management practices (good rotation, fungicides) employed together offer the best possible control of this disease. Black shank can be caused by several races of *P. nicotianae, but now black shank is* almost always caused by either race 1 or race 0. Race 0 was the predominant strain present in most burley tobacco fields until extensive use of "L8" hybrids led to many areas having a mixture of race 0 and race 1. Burley tobacco cultivars KT 206LC, KT 209LC, KT 210LC, KT212LC, NC7 LC, HB 3307PLC, and HB 4478PLC and dark tobacco cultivars PD 7302, PD 7309, and PD7318 possess a source of black shank resistance (the Ph gene) similar to L8, and widespread planting of these cultivars has resulted in race 1 predominating in fields where these cultivars have been used.

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 or where very good rotation has been practiced. KT 206LC, KT 209LC, , KT 210LC, KT212LC, NC7 LC, HB 3307PLC, and HB4478PLC and PD 7302, PD 7309, and PD7318 possess "near immunity" (black shank resistance rating of 10 in tables in the Selecting Burley Tobacco Varieties and Choosing Dark Tobacco Varieties sections of this guide) to race 0, causing them to favor rapid increase of race 1 to potentially damaging levels. Because of this trend, fields with a history of black shank and/or a short crop rotation interval should be planted with cultivars possessing moderate to high resistance to race 1 (4-8 on the rating scale). These cultivars always 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. 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.

For chemical control of black shank, use products containing mefenoxam (Ridomil Gold, Ultra Flourish) or metalaxyl (MetaStar) (Table 2) in conjunction with resistant varieties (4 or greater on the rating scale) and crop rotation. These products cannot be used for black shank control in Pennsylvania. In most cases, fungicides will not provide acceptable control of black shank if applied to varieties with little or no resistance. Good soil moisture is needed for best performance of these products because root uptake is required for them to be effective. Where black shank has been severe, apply a fungicide no more than seven days before planting at the rates found in Table 2. 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 allow the initial application after planting. Such an application, which should occur as soon as possible after transplanting, 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. Another approved method for the initial application of Ridomil Gold is the transplant water method. Ridomil Gold is labeled at 4 to 8 fluid ounces per acre and should be applied in at least 200 gallons of transplant water per acre to avoid damage to plants.

For full-season control of black shank, supplemental applications of Ridomil Gold (1 pt), Ultra Flourish (2 pt), or MetaStar (2 qt) can be made at layby **or** at first cultivation and again at layby. The MetaStar label prohibits post-plant applications when more than 2 quarts of MetaStar was used prior to planting, or if none was used. Applications of these black shank fungicides should total no more than 3 pints per acre for Ridomil Gold, 6 pints per acre for Ultra Flourish, or 6 quarts per acre for MetaStar. These applications 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, thereby reducing the effectiveness of the treatment. Some soil fumigants are labelled for black shank control but are intended to supplement early fungicide applications for black shank and to broaden control to include other soilborne pathogens (when present).

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 varieties has reduced the importance of this disease in recent years; however, dark varieties generally lack resistance 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 a number of 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. Byproducts 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 on burley). Black root rot can be aggravated by high 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 overwinter normally in traditional burley growing areas and requires a living host to survive. When tobacco is killed by frosts or freezes in late fall, surviving *P. tabacina* is eliminated as well. Epidemics of blue mold normally begin from introductions of *P. tabacina* from outside areas where *P. tabacina* is present year-round. 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 Selecting Burley Tobacco Varieties and Choosing Dark Tobacco Varieties sections of this guide). Two varieties, NC 2000 and NC 2002, have moderate-to-high resistance to blue mold, while KT 206 and TN 90 have low-to-moderate resistance. Be mindful that some of these varieties may not be resistant to other diseases that may be encountered.

Chemicals registered for control of blue mold are listed in Table 1. 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 forecasted 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 plus a mancozeb fungicide, our results indicate that Quadris provides consistent and effective control of blue mold if applied regularly on a preventive basis. Keep in mind that Quadris is a protectant fungicide and 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.

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

Fungicide	Season Rate/A	Pre-plant or at-planting applications			Post-plant applications	
		Method	**Rate/A***	**Remarks**	**Rate/A***	**Remarks**
Ridomil Gold SL	3 pt	Pre-plant only	1-2 pt	Apply to soil within 1 week be-fore planting and incorporate into the top 2-4 inches of soil.	--	--
		Pre-plant + post-plant	1 pt	Apply to soil within 1 week be-fore planting and incorporate into the top 2-4 inches of soil.	1 pt	Make 1st application as near as pos-sible to transplanting if no pre-plant application was made or if black shank is expected early in the sea-son. Otherwise, make application(s) at layby or at 1st cultivation and layby.
		Transplant water + post-plant	¼-½ pt	Apply in no less than 200 gal-lons of transplant water per acre.	1 pt	Make subsequent application(s) at 1st cultivation and/or layby.
Ultra Flourish	6 pt	Pre-plant only	2-4 pt	Apply to soil within 1 week be-fore planting and incorporate into the top 2-4 inches of soil.	--	--
		Pre-plant + post-plant	2 pt	Apply to soil within 1 week be-fore planting and incorporate into the top 2-4 inches of soil.	2 pt	Make 1st application as near as pos-sible to transplanting if no pre-plant application was made or if black shank is expected early in the sea-son. Otherwise, make application(s) at layby or at 1st cultivation and layby.
MetaStar 2E	12 pt	Pre-plant only	8-12 pt	Apply to soil just prior to plant-ing and incorporate into the top 2-4 inches of soil.	--	--
		Pre-plant + post-plant	4 pt	Apply to soil just prior to plant-ing and incorporate into the top 2-4 inches of soil.	4 pt	Do not make a post-plant applica-tion of MetaStar if more than 4 pt was used pre-plant or if none was used pre-plant. Post-plant applica-tion(s) may be made at layby or at 1st cultivation and layby.

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

If blue mold is present in a field, apply Forum tank-mixed with a mancozeb fungicide, and follow with Quadris seven to 10 days later. Make sure to not make back-to-back applications of Quadris; rotate to another fungicide or program (mancozeb product or Forum plus a mancozeb product) after each application of Quadris. Good coverage is critical to getting good disease control with this product—the use of drop nozzles is recommended. Quadris can be applied up to the day of harvest, making this fungicide a good option for post-topping control of other leaf-spotting diseases. 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, mancozeb, Aliette WDG, and Actigard. Forum is a liquid formulation of dimethomorph, the same active ingredient found in Acrobat 50WP, a product no longer on the market. According to the Forum label, these products must be tank-mixed with another blue mold fungicide for management of resistance; mancozeb works well in this role. As with Quadris, good coverage is very important to get best results with Forum, and the application volume and rate must be increased as the crop increases in size (Table 1). Revus is a new product from Syngenta that is labeled only for control of blue mold. Resistance management is an important consideration with Revus. Growers must not make more than two consecutive applications of Revus before switching to a fungicide with a different mode of action (mancozeb or Quadris are good choices). Revus and Forum have the same mode of action and should never be tank-mixed together or sprayed in rotation with each other.

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 can 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 provide good protection against blue mold up to topping time. Do not apply Actigard to burley tobacco until plants are greater than 18 inches tall (12 inches for dark tobacco) to avoid serious injury. If blue mold threatens tobacco less than the recommended height, use another fungicide to protect until Actigard can be applied. Do not apply Actigard if plants are stressed from drought or other environmental factors, as severe injury could occur.

Aliette has been available for several years on tobacco and is 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-10-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. Our experience with Aliette is limited at this time; however, results from testing in Kentucky 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. Resistance to mefenoxam (Ridomil Gold, Ultra Flourish) or metalaxyl (MetaStar) is widespread in populations of the blue mold pathogen, making these products a risky choice.

Brown spot and ragged leaf spot. These diseases tend to be problematic on burley and dark tobacco later in the season but rarely 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 that only occasionally causes significant problems. Leaf loss can be severe in rainy 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 percent or more have been observed in some areas. High humidity and moderate temperatures favor this disease, making target spot a serious problem in fields that are shaded or have poor air drainage. 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 brown spot will also help control target spot and frogeye. In addition, do not under-fertilize 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.

Quadris is the only labeled option for management of frogeye and target spot (Table 1). However, Quadris cannot be applied back-to-back—unrelated fungicides must be applied between Quadris applications. Although mancozeb fungicides are only slightly effective against frogeye and target spot, they are the only choice for this purpose at this time. Rates and timing of Quadris applications depend on many factors, such as the level of leaf spot control desired, field history, rainfall, and the type of tobacco grown. Generally, a rate of 8 fluid ounces per acre provides adequate control of fungal spots while minimizing the severity of flecking caused by Quadris. A 10- to 14-day schedule may be needed during rainy periods. A Quadris program should be started early for most effective control of the leaf spots. The degree of control needed depends on the expected disease severity (crop rotation history, degree of air drainage for the site) and on your tolerance level for leaf spots. For frogeye control, Tennessee research has indicated a need to begin as early as two to three weeks after planting. For target spot control, Kentucky research has shown that the spray program can be delayed until plants are 24 to 36 inches tall. Although the leaf spots cause most of their damage after topping, early fungicide applications will minimize late-season damage by suppressing the buildup of the pathogens.

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 poor rotations. 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. Crop rotation is equally important as a preventive measure. Avoid planting tobacco behind sweet potato, cotton, or any other crop that we already know has significant susceptibility to Fusarium. For some, avoidance of fields with a history of severe Fusarium wilt may be the best plan if at all possible. Certain varieties of burley tobacco have moderate resistance to Fusarium wilt, including KY 14×L8 and NC 7. 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. When dealing with both black shank and Fusarium wilt in the same field, KT 210 (a new variety with good resistance to black shank plus moderate resistance to Fusarium wilt) should be planted.

Hollow stalk. This disease is caused by the same bacterium, *Erwinia carotovora* subsp. *carotovora*, that causes black leg or bacterial soft rot on transplants, and is typically found after topping. Warm and humid conditions favor development of hollow stalk. To reduce incidence of this disease, 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 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. Diseases caused by viruses are common in Kentucky, and 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 certain virus diseases of tobacco (see Selecting Burley Tobacco Varieties and Choosing Dark Tobacco Varieties sections of this guide). 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 certain diseases; don't plant tobacco near vegetables 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.

Chemicals for Disease Control

Several fumigants are registered for use on tobacco for preplant suppression of soilborne pathogens and nematodes. Nematodes are rarely a serious problem in burley tobacco fields. Chloropicrin used as a preplant soil treatment will reduce early populations of *P. nicotianae, Rhizoctonia, Fusarium, Pythium,* and *Thielaviopsis,* but the level of control to be expected is uncertain. Soil fumigants are hazardous, expensive, must be applied with specialized equipment, and will probably not be an economically viable choice for most producers.

Tables 1 and 2 list labeled chemicals for use in the production of burley and dark tobacco as of December 2014. As always, read all product labels carefully and follow all directions provided by the manufacturers. Each product has specific use directions that should 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.

Insect Pest Management

Lee Townsend

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 sap feeding reduces plant vigor and growth, and they may introduce and spread viruses in the crop. 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.

Pretransplant

Soil Applications

The soil insecticides Brigade, Capture, Lorsban (and generic versions) can be used for cutworm or wireworm control (Table 2). They should be applied one to two weeks before transplant and immediately disked into the top 2 to 4 inches of soil. A soil insecticide should be used when going into established sod fields because of the potential for wireworm damage.

Tray Drench Applications

Admire Pro 4F (and generic versions that contain the active ingredient imidacloprid) and Platinum are systemic insecticides that are labeled for application as a drench to float trays or flats prior to transplant. Most rates are expressed as fluid ounces per 1,000 plants (Table 3). Agitate or mix the insecticide frequently to keep it from settling in the tank. The plants should be watered from above after application to wash the insecticide from the foliage into the potting 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), and a new product, Coragen (Table 4). Coragen is labeled for worm control only. When applied in transplant water, this product will provide residual control of hornworms and budworms. The length of control depends on the amount of product applied and the volume of transplant water used. A minimum of 100 gallons per acre is recommended to ensure adequate distribution of pesticide solution in the root zone, and control will 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 cause a delay in control.

Premix Orthene 97 (or a generic equivalent) 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, and late-set fields are at greater risk to tobacco 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. 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.

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

Stage of Season	Insect	Treatment Guidelines
1-4 weeks after transplant	Cutworms	Five or more freshly cut plants per 100 plants checked.
	Flea Beetles	Three or more beetles per plant on new transplants, 10 or more beetles on 2-4 week-old plants, 60 or more beetles on plants more than 4 weeks old.
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.

IMPORTANT: Products containing endosulfan (Thiodan, Phaser, etc.) are no longer recommended because of concerns about the residues of this insecticide on tobacco. Many products containing other active ingredients are available and provide excellent pest control.

Major Insect Pests

Tobacco aphid infestations generally 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. Fields not receiving a preventive treatment at transplant 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. *An insecticide application is recommended if colonies of about 50 aphids are found on 10 percent or more of the plants that are examined. Table 5 contains a list of insecticides and restricted-use pesticides labeled for control of tobacco aphids.* 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.

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. Direct leaf damage and stunting can reduce 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 at least 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 gallons of water per acre 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. Use the highest labeled rates for heavy populations.

Table 2. Pre-transplant soil applications for tobacco fields

Pre-plant Insecticides	Rate/Acre	Labeled Pests
Lorsban 4E chlorpyrifos (and generics)	2 qt	Cutworms, Wireworms
Restricted Use Pesticides		
Brigade EC (bifenthrin) Capture LFR	4 to 6.4 fl oz 3.4 to 8.5 fl oz	Cutworms, White grubs, Wireworms

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

Table 3. Tray-drench application of insecticides

Insecticide	Rate	Comment
Admire 2F (and generic formulations)	1 fl oz/1,000 plants 1.4 to 2.8 fl oz/1,000 plants	Aphids, flea beetles, wireworms (high rate)
Admire Pro 4F	0.5 fl oz/1,000 plants 0.6 to 1.2 fl oz	
Orthene 97	3/4 lb/A	Flea beetles, cutworms
Platinum 2 SC	0.8 to 1.3 fl oz/1,000 plants	Aphids, flea beetles
	1.3 fl oz/1,000 plants	Wireworms

Table 4. Transplant—water application of insecticides

Insecticide	Rate	Comment
Admire 2F (and generic formulations)	1.4 fl oz/1,000 plants	Aphids, flea beetles, wireworms (high rate)
	1.4 to 2.8 fl oz/1,000 plants	
Admire Pro	0.6 to 1.2 fl oz/1,000 plants	
Coragen SC	5 to 7.5 fl oz	Budworms, hornworms
Durivo	0.6 to 1.6 fl oz/1,000 plants	Aphids, budworms, flea beetles, hornworms, thrips, wireworms
Orthene 97	3/4 lb/A	Flea beetles, cutworms
Platinum 2 SC	0.8 to 1.3 fl oz/1,000 plants	Aphids, flea beetles
	1.3 fl oz/1,000 plants	Wireworms
Restricted Use Pesticides		
Brigade 2E Capture LFR	4 to 6.4 fl oz/A 5.3 to 8.5 fl oz/A	Cutworms, wireworms

Table 5. Insecticides labeled for foliar application for control of tobacco aphids

Insecticides	Rate/A	Harvest Interval (days)
Actara 25% WDG	2 to 3 oz	14
Assail 30 G	1.5 to 4 oz	7
Belay 2.13 SC	3 to 4 fl oz	14
Brigade	2.56 to 6.4 fl oz	Not after layby
Brigadier	3.8 to 6.4 fl oz	Not after layby
Capture LFR	3.4 to 8.5 fl oz	Not after layby
Endigo ZC	4 to 4.5 fl oz	40
Fulfill 50 WDG	2.75 oz	14
Orthene 97	3/4 lb	3
Provado 1.6 F	2 to 4 fl oz	14
Voliam Flexi WDG	2.5 to 4 oz	14
Restricted Use Pesticides		
Besiege	5 to 9 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

Hornworms eat large amounts of tobacco foliage. The first brood appears in June. A second brood 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 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 percent 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. Apply an insecticide with a short preharvest interval if necessary to prevent taking significant numbers to the barn (Table 6). There are no treatments to control hornworms effectively on housed tobacco.

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 three or more beetles per plant is enough to cause significant damage. Treat if there are three or more beetles per plant during the first two weeks after transplant. Table 7 provides information on insecticides and restricted-use pesticides labeled for flea beetle control. Established plants rarely need protection from this insect.*

Table 6. Insecticides labeled for foliar application for control of budworms and hornworms

Insecticides	Rate/A	Harvest Interval (Days)
Agree WG (3.8% Bt aizawai)	1 to 2 lb	0
Assail 30 SG	2.5 to 4.0 oz	7
Belt 4 SC	2 to 3 fl oz	14
Biobit HP (6.4% Bt kurstaki)	½ to 1 lb	0
Biobit F (6.4% Bt kurstaki)	1 to 4 pt	
Coragen SC	3.5 to 7.5 fl oz	1
Denim 0.16 EC	8 to 12 fl oz	14
Dipel 10 G	5 to 10 lb	0
Dipel DF	½ to 1 lb	
Dipel ES	1 to 2 pt	
Javelin WG	1/8 to 1¼ lb	
Lepinox WDG	1 to 2 lb	
Orthene 97	3/4 lb	3
Sevin 80S	1-1/4 lb	0
Tracer 4 SC	1.4 to 2.9 fl oz	3
Voliam Flexi WDG	4 oz	14
XenTari DF	½ to 2 lb	0
Restricted Use Pesticides		
Besiege	5 to 9 fl oz	40
Brigade 2EC	2.56 to 6.4 fl oz	Do not apply later than layby
Capture LFR	3.4 to 8.5 fl oz	
Endigo ZC	4 to 4.5 fl oz	40
Lannate SP	½ lb	14
Warrior 1 CS	1.9 to 3.8 fl oz	40

Table 7. Insecticides labeled for foliar application for control of flea beetles

Insecticides	Rate/A	Harvest Interval (Days)
Actara 25% WDG	2 to 3 oz	14
Carbaryl 4L	1 qt	0
Sevin 80S	1-1/4 lb	
Orthene 97	½ lb	3
Provado 1.6 F	4 fl oz	14
Voliam flexi	2.5 to 4 oz	14
Restricted Use Pesticides		
Besiege	5 to 9 fl oz	40
Brigade 2EC	2.56 to 6.4 fl oz	Do not apply later than layby
Brigadier	5.1 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
Warrior 1 CS	1.92 to 3.84 fl oz	

Occasional Pests

Armyworms may be present in no-till tobacco fields transplanted into burned-down grass or small-grain cover crop. Belt, Besiege, Brigade, Brigadier, Endigo ZC, and Capture are labeled for control.

Cutworms may be present in tobacco fields because of early season weed growth. Often they are relatively large by the time tobacco is set in the field, making control more difficult. Cutworms feed at the base of transplants and can cut them off at ground level or belowground if the soil is dry. Moths are active in March and April, laying their eggs on low, spreading weeds.

Damage potential is highest in late-set fields where there has been a flush of winter annual weeds. Cutworms will begin to feed on the weeds and switch to transplants when the weed growth is removed. A foliar spray should be applied if five or more cut plants are found per 100 plants checked. Belt, Besiege, Brigade, Brigadier, Endigo ZC, Orthene 97, and Warrior 1 CS can be used as a broadcast spray.

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.

Japanese beetles can feed on tobacco. The damage usually is confined to a small number of plants. Actara, Besiege, Brigadier, Endigo ZC, Orthene, Provado, Sevin 80S, Warrior, or Voliam Flexi may be used if Japanese beetles are causing significant damage.

Table 8. Insecticides labeled for foliar application for control of grasshoppers

Insecticides	Rate/A	Harvest Interval (Days)
Orthene 97	1/4 lb	3
Restricted Use Pesticides		
Besiege	5 to 9 fl oz	40
Brigade 2EC	2.56 to 6.4 fl oz	Do not apply later than layby
Capture LFR	3.4 to 8.5 fl oz	
Endigo ZC	4 to 4.5 fl oz	40
Lannate 90 SP	½ lb	14
Warrior 1 CS	1.92 to 3.84 fl oz	

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. Acephate, Besiege, Brigade, Brigadier, Endigo ZC, Orthene, or Warrior are labeled for stink bug control. Treatment is not justified unless stink bugs are found in the field.

Thrips can feed on tobacco plants but usually are only a temporary problem. Several insecticides are labeled as foliar sprays for thrips control.

Safety and Health in Tobacco Production

Mark Purschwitz, John Wilhoit, and Bob Pearce

Production agriculture is a hazardous occupation. 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 on harvest field safety.

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 of your barns for cracks and damage, since broken rails are a major cause of falls while hanging tobacco. Needless to say, these falls can be extremely serious and can result in everything from broken bones to broken necks and permanent paralysis. Do not assume that the rails are in the same condition they were last year. Look them over carefully and repair or replace rails with even a small amount of weakness. 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 some of the very large barns that have become more common in burley tobacco production.

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, is the hitch on the rear of the leading wagon in good condition? Do you have safety hitch pins (pins with retainers so they cannot pop out) for all your wagons? 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? While seatbelts are not recommended for tractors and other machines that do not have roll-over protective structures (ROPS), do your riders have 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?

Harvest Field Safety and Health

Tobacco harvest involves both injury and illness hazards. Hazards like the tobacco knife and the 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 serious cuts 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. Problems that can result from excessive heat include heat rash (a skin irritation from excessive sweating), heat cramps, heat exhaustion (with symptoms like heavy sweating, rapid breathing, and a fast but weak pulse) and heatstroke (a life-threatening illness resulting from very high body temperatures with symptoms like dizziness, dry skin, and a rapid but strong pulse). Heatstroke requires immediate emergency care.

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 mentioned previously, rails 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 accidents while up in the barn. Horseplay should not be allowed 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 during hanging operations should be strictly 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 power stalk choppers, which can be very loud. The big tobacco balers that have become much more common have pinch points that workers should be aware of. Workers operating the hydraulic valves on these balers need to be sure that their coworkers are well clear of the balers when they are in operation.

Stripping may involve dusty conditions. When dust is an issue, good ventilation and dust filtering is 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 wood-working 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") and is 95 percent effective when properly fitted, which is an acceptable level of effectiveness. An 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. Again, your safety supplier can guide you on selection.

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 seems to care more about personal convenience. 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 tall implements that block the view of the tractor should have bright slow-moving vehicle (SMV) emblems. These emblems must be kept clean and replaced when they fade. Other high-visibility tape, bright fluorescent orange for daytime and reflective red for dusk and nighttime, should be added to the extremities of equipment to help prevent collisions when passing. All lights should be in working condition and used day or night; headlights, taillights, and flashing amber lights should be used to make equipment more visible. 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 the vision of approaching motorists.

Another important aspect of roadway safety is maintaining control of equipment. Safety hitch pins (as mentioned previously) have retainers to prevent popping out and 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. Allowing adequate time to cross or pull onto roads, pulling over to allow following traffic to pass, and staying in your own lane but being aware when your equipment is too wide to stay in your lane are all important operator skills and courtesies.

Besides the potential for serious injury or death, 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 important 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 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 spacing, the center of gravity kept low (especially when using a loader), and the operator 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.

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

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 for farm-related hazards and operating machinery according to manufacturers' specified practices.

Introductory Safety Training for Tobacco Workers (ID-204), an English/Spanish bulletin, is available from UK Cooperative Extension. This bulletin provides basic training using a farm walk-around approach by the grower with the workers. The publication provides basic introductory training and is not intended to cover all possible hazards on a farm.

Appendix I

Worker Protection Standard Checklist

Lee Townsend

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 instructions.

Notification—Signs for Posting Information at Central Location

☐ WPS Safety Poster
Gempler P928
$ 6.25 each

☐ Nearest Medical Facility Sign (or make your own)
Gempler X1584
$ 10.50 each

☐ Reusable Pesticide Application Poster (or make your own)
Gempler P942
$ 9.95 each
Post before application is made, keep posted until 30 days after Restricted Entry Interval (REI) expires.

Field Location and Description	Product Name and EPA Registration Number	Active Ingredient(s) in Product	Time and Date of Application	Restricted Entry Interval

☐ Corrugated WPS Sign
Gempler 2256
$ 3.95 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 not to enter treated areas during the REI. Some pesticide labels require both oral warnings and posting of treated areas.

☐ Pesticide handlers must understand all labeling information for the pesticides they are using and must have access to labeling.

Decontamination—Must be within a quarter mile of workers/handlers. Maintain for seven to 30 days after REI applies (see label).

Workers—Water to wash hands, soap, and single-use towels. Must not be in area being treated or under REI.
Handlers—Water to wash entire body, soap, single-use towels, and clean towels. Also must be where personal protective equipment is removed and in mix/load area. Supplies must be enclosed.

Personal Protective Equipment (PPE)

Employer must provide and maintain clean PPE required by label 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.

☐ Chemical resistant gloves (15 mil unlined nitrile)
Gempler 10212
$ 3.00 (pair)

☐ Unhooded DuPont Tyvek Coverall
Gempler 214559
$ 6.95 each

☐ Low-cost Anti-Fog Chemical Splash Goggles
Gempler 10507
$ 4.75 each

☐ Moldex Pesticide Respirator
Gempler G80002
$ 37.20 each

☐ Replacement cartridges
Gempler G8100M
$ 64.60/box (10 cartridges)

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

☐ Provide transportation to medical facility.

☐ Supply medical personnel with product name, EPA registration number, and active ingredient(s). Describe pesticide use and give details about exposure.

Training—Valid for five years if records or EPA card is available. Certified pesticide applicators do not need WPS training and can perform WPS training. Training aids are available from the Extension office.

☐ Workers need basic training before they begin and must complete training within five 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 G95003 (worker)
$ 8.40 each
Gempler G95004 (handler)
$ 8.50 each

Some Generic Insecticides by Active Ingredient

Generic formulations are available for many active ingredients labeled for tobacco (Table 1). Amounts of active ingredients in and application sites of generic products may differ from those in name brands. Check labels carefully before purchase.

Information Summary Table for Tobacco Insecticides

Table 2 is provided for a quick comparison of insecticides labeled for tobacco. Insecticides are listed alphabetically by pesticide common name (usually present in the active ingredients section of the product label). One or more brand names are included along with the Restricted Entry Interval (REI) and mode of action group number. Brand names of restricted use pesticides appear in bold italics .

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 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.

Mode of Action Group. A numerical classification system has been developed to make it easy to recognize the modes of action of insecticide products. Insecticides with the same mode of action belong to groups with unique numbers. Selection of a labeled product from a different number category (different mode of action) will help to slow down the development of resistance to either group. For example, alternate use of pyrethroid insecticides and pyrethrins sprays (Category 3) with labeled organophosphate insecticides (Category 1B). Always avoid tank-mixing products with the same mode of action. These mode of action group codes are on many pesticide labels and have been developed by the Insecticide Resistance Action Committee (IRAC).

Table 1. Common brand names of products for selected active ingredients. Always check label of pesticides to insure the specific product is labelled, and verify the rate for the intended crop and pest**.**

Active Ingredient ("Brand" Name)	Generic Product Names
Acephate (Orthene)	Acephate, Bracket
Bifenthrin (Capture)	Bifen, Bifenthrin, Bifenture EC, Fanfare, Sniper, Tailgunner, Tundra
Bifenthrin + imidacloprid	Skyraider, Swagger, Tempest
g-Cyhalothrin (Warrior)	Declare, Proaxis
l-Cyhalothrin	Grizzly, Kaiso, Kendo, LambdaT, Lambds-cy, Lambdastar, Lamcap, Province, Silencer, Tiaga, Willowood Lambda
Chlorpyrifos (Lorsban)	Chlorpyrifos, Govern, Hatchet, Saurus, Vulcan, Warhawk, Whirlwind, Yuma
Cyfluthrin (Baythroid)	Tombstone
Imidacloprid (Admire)	Advise, Alias, Amtide Imidacloprid, Couraze, Kilter, Macho, Malice, Mana Alias, Midash, Nuprid, Pasada, Prey, Sherpa, Widow, Wrangler
Spinosad	Blackhawk

Table 2. Restricted Entry Interval (REI) and mode of action group number for selected insecticides labled for tobacco

Common name	Brand Name	Restricted Entry Interval (hours)	Mode of Action Group
Acephate	Acephate, Bracket, Orthene	24	1B
Acetamiprid	Assail 30 G, Assail 70 WP	12	4A
Bifenthrin	***Brigade 2E*** ***Capture LFR***	12	3
Bt aizawai	Agree WG, Xentari DF	4	11B1
Bt kurstaki	Dipel DF, Javelin WG Lepinox WDG, etc.	4	11B2
Carbaryl	Sevin XLR Plus	12	1A
Chloranthranilprole (+ cyhalothrin)	Coragen ***(Voliam xpress)***	4	28 (3 + 28)
Chlorpyrifos	Lorsban and generics	24	1B
Clothianidin	Belay 16 WSG	12	4A
Flubendiamide	Belt 4 SC	12	28
lambda-cyhalothrin	***Warrior*** and generics	24	3
emamectin benzoate	***Denim EC***	48	6
Ethoprop	***Mocap 15G***	48*	1B
Imidacloprid	Admire and generics	12*	4A
Methomyl	***Lannate***	48	1A
Pymetrozine	Fullfil	12	9B
Spinosad	Tracer	4	5
Thiamethoxam (+ chlorantraniliprole)	Actara, Platinum (Voliam flexi)	12	4A (+28)

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