2011-2012 Kentucky & Tennessee TOBACCO Production Guide

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Production Guide

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Introduction

Bob Pearce, Paul Denton, and Andy Bailey

Tobacco growers in Kentucky and Tennessee have faced many challenges during the past two years, including weather, market instability, and rising production costs. Buying stations have closed or moved, and contract volumes have been significantly reduced for many burley growers. These changes have impacted some regions of both states much more than other regions. Dark tobacco contract volumes have been more stable than burley, but dark tobacco growers have had challenges as well, including shortages of wood and sawdust needed to produce dark-fired tobacco. Labor costs have continued to rise as tobacco growers struggled to keep pace with changes in the H2A labor program that allows them to legally employ migrant workers. To top it off, uncertainty about future regulatory action hangs over the entire tobacco industry like a heavy cloud. Still, tobacco remains as an important commodity in the agricultural economy of the region as growers prepare for future seasons.

The 2009 growing season was unseasonably cool and wet over most of Kentucky and Tennessee. Frequent rains during May and June complicated planting and resulted in much of the crop being planted later than desired. Rain continued over most of the growing area through the remainder of the season, which resulted in a typical wet weather tobacco crop that appeared to be very large and heavy in the field but was somewhat disappointing for final cured leaf yields. Even in late September and early October, heavy rains continued to hamper harvest efforts. The late-season rains resulted in some of the worst cases of leaf drop in recent memory.

Despite the wet weather, most tobacco diseases were fairly mild in 2009. Black shank incidence was relatively low compared to recent seasons, most likely because of the cool weather and absence of drought stress during the season. Blue mold made an appearance in mid-July in eastern Kentucky and Tennessee and caused some significant damage in individual fields, but it was not a major factor for the overall crop. Insect pressure was fairly light throughout the region in 2009. Weed pressure was moderate due to the favorable moisture conditions for seed germination and the delay in cultivation as a result of wet soils. Growers faced challenges with sucker control during 2009, as frequent rainfall events often washed off treatments shortly after application.

For burley and dark air-cured growers, the high humidity conditions during curing resulted in houseburn and moldy leaf. Overall the color of the cured leaf was much darker than in previous seasons, but significant amounts of mold did reduce the value of some leaf.

A wet start followed by hot, dry conditions characterized the tobacco growing season throughout much of Kentucky in 2010. In early May a major weather system dumped 6 to 12 inches of rain across much of Kentucky and Tennessee, flooding many low-lying areas and saturating soils. In most areas it took nearly two weeks before transplanting could get under way again. This delay resulted in a later-than-normal crop. By early June western Kentucky was already drying out, while rain continued to be plentiful for southern and central Kentucky. In late June temperatures were running above 90°F, and this heat wave continued throughout July, August, and September. Dry weather eventually spread across central and northern Kentucky; however, southern Kentucky and northern Tennessee continued to have favorable moisture conditions through late August. August and September were very dry across Kentucky, with many weather stations recording less than an inch of rain each month. Many areas of eastern Tennessee had near-normal rainfall in the late summer and early fall after a dry start. Most of the Tennessee growing area received some rainfall from the remnants of tropical storms in early September, improving conditions for the late-set crop. Early planted tobacco had slightly better than average yields overall, but late-set tobacco in many areas was hit hard by the drought, and yields were reduced. Harvesting of tobacco continued well into October, due to the late start for many crops. Very dry conditions persisted through September and October in much of Kentucky, leading to low relative humidity during curing. These conditions resulted in the crop curing too quickly and having a tendency toward bright colors. The situation was better in the burley growing areas of Tennessee, especially the northeast, where fall rainfall was near normal and humidity more in the desirable range for good curing.

From a disease standpoint, black shank was severe on many burley crops. KT 206 LC and KT 209 LC were the two most widely grown burley varieties in 2010. While these varieties do have the best black shank resistance currently available, they are not totally immune to the disease and can suffer significant losses in the absence of good rotation and fungicide use. Frogeye leaf-spot was widespread and caused significant leaf loss in many late burley crops.

Early weed pressure was average, as there was sufficient moisture for the activation of pre-emergent herbicides. Late-season weed pressure was significant on some crops, since the tobacco never reached full canopy closure due to the dry weather. A few cases of damage to tobacco from off-target herbicide applications were reported in 2010. However, this damage did not seem to be as common as in 2009, probably because the problems in 2008 and 2009 raised everyone's awareness. In particular, tobacco growers need to be aware that some pasture weed control products can be very persistent in soils and may affect tobacco in the year(s) after application and that some of the materials can be spread in manure from animals consuming treated forages.

Early-season insect pressure from hornworm and budworm was unusually high in Tennessee and southwestern Kentucky, and significant damage was done in some fields before growers recognized the problem and began control measures. Hornworm pressure was light in central Kentucky until topping time, but a flush of hornworms was seen in late July.

Sucker pressure was average, and growers using a combination of MH with a local systemic on burley generally had good control. However, a few situations of reduced control may have been due to application of sucker control materials to tobacco that was under stress. Burley growers in some areas were offered the opportunity to grow parts of their crop without the use of MH. Sucker control results were mixed when growers attempted to apply MH-free protocols using high clearance sprayers. Sucker control was good to moderate in the lower two-thirds of the plant, but often one or two suckers at the top of the plant were poorly controlled.

Dark tobacco crops in western Kentucky and northwestern Tennessee experienced many of the same weather patterns that occurred in other parts of Kentucky. Conditions were extremely wet in April and early May, causing delays in field preparation and transplanting. Heavy early-season rainfall caused soil erosion in many fields, including some strip-tillage dark tobacco fields. Moisture conditions were below average at most locations in July, August, and September, with above-average temperatures in much of late June, July, and August.

Crops transplanted in May and early June experienced good rainfall for herbicide activation, although weed pressure was slightly above average, particularly where herbicides were incorporated. A few cases of damage from off-site herbicide applications were also seen. Insect pressure from hornworm and budworm was well above average in western Kentucky and northwestern Tennessee. Early-season damage from black cutworm, flea beetle, and even yellow-stripped armyworm was also seen in this region. Aphid levels, however, were very low.

Dark tobacco sucker control was considered average in 2010, with fairly strong sucker pressure despite the dry conditions.

Although black shank is always the most severe disease affecting dark tobacco, the occurrence of black shank in 2010 was slightly below normal. In many cases, black shank appeared later than normal, and this delay helped lessen some of the damage. Newer varieties such as PD 7309LC and PD 7318LC were widely grown in 2010 and performed relatively well in black shank fields that were predominantly race 0. However, levels of race 1 black shank appear to be increasing throughout the dark tobacco region. The new PD 7305LC variety as well as KT D6LC and DT 538LC performed relatively well in fields with race 1 black shank. Leaf damage from target spot, frogeye leaf-spot and angular leaf-spot were slightly below normal. An early frost on October 4 caused some damage to late crops still in the field that were transplanted in low-lying areas.

Under ideal conditions, growing a good crop of tobacco is relatively easy, but when conditions are challenging it takes good management skills and attention to detail to make tobacco a profitable crop. This publication is designed to provide the good manager with the latest information for the production of high yielding, good quality tobacco. Contact your county Extension office for additional information and other supporting materials and publications.

Tobacco Economics in the Post-Buyout Era

Will Snell and Laura Powers

The economic landscape for tobacco production in the post-buyout era has been different compared to what growers experienced during the decades of the federal tobacco program. No longer do growers benefit from the price support system that assured a minimum price for their tobacco, a guaranteed buyer, and minimal price volatility within and across marketing seasons. However, growers are not faced with production (quota) constraints, the extra cost of renting additional production rights, or quota instability and all the uncertainty that existed with regards to the continued existence of the former federal tobacco program.

The movement to production contracts by most growers has had the tendency to reduce some of the risks but also adds new ones. Contracting growers have a legal agreement with a buyer that states the company will purchase the grower's crop (as long as the grower fulfills contracting terms) and a pre-marketing price schedule for a given set of grades/qualities established and determined solely by the contracting company. However, the post-buyout marketing environment requires growers to pay more attention to various quality-enhancing production and management practices (e.g., chemical/fertilizer applications, disease control, curing management, market preparation), as there is no longer a market through which the government, through the cooperatives, purchases tobacco rejected by the companies. Furthermore, contracting growers under the current marketing environment do not have access to a third party to settle any grade disputes.

Presently, the existence of a few remaining auction markets provides an alternative system for those growers who opt to not be bound by a contract and as an outlet for contracted tobacco rejected by the tobacco companies. However, these markets do not guarantee a buyer or an established set of prices determined prior to marketing. Grower prices and buyer acceptance of tobacco under both systems should be fairly consistent and favorable during periods of short supplies relative to demand. However, when supplies become ample relative to demand, growers will experience more price volatility as buyers become more selective. Excess supplies across marketing seasons will induce buyers to consider various options such as lowering contract prices, decreasing contract volume, eliminating contract growers, and/or reducing their participation in the auction marketing system.

Competitive prices, quality production, and future policy/regulatory changes will dictate future marketing opportunities for U.S. tobacco growers. Domestic use continues to decline in response to declining cigarette production/consumption, declining leaf usage per cigarette, use of imported leaf, and regulatory uncertainty. Internationally, favorable prices (due to

lower post-buyout market prices and favorable exchange rates) have improved the price competitiveness of U.S. tobaccos in the international market, but regulatory concerns and increasing supplies pose threats to future U.S. burley demand overseas. Alternatively, dark tobacco growers should continue to benefit from a sustained expansion in domestic smokeless tobacco consumption, limited off-shore competition, and favorable price incentives offered by smokeless tobacco manufacturers.

In summary, the marketing environment in the post-buyout era provides opportunities and challenges for both burley and dark tobacco growers. The former federal tobacco program tended to minimize growers' price risk and generally insured profitability on a per-pound basis (assuming a good quality yielding crop), but subjected farmers to much quota and income instability in order to balance supply and demand. Income for U.S. tobacco farmers will now have to be earned in a marketing environment characterized by a concentrated group of buyers and stiff international competition. Consequently, U.S. tobacco growers will have to pay a lot more attention to cost-cutting measures (along with producing quality leaf) if they are going to survive and prosper in the post-buyout era. Thus, it becomes critically important that producers not only maintain detailed production records on their cost of production, but also understand how to develop and interpret tobacco budgets.

Budgeting and Production Economics

Economists generally classify production expenses into two categories: variable and fixed. Variable expenses are those costs that are incurred directly with the production of the crop (e.g., fertilizer, chemicals, labor) and that depend on the scale of production for a particular year. If no production occurs, these expenses will be zero. Fixed expenses are more commonly referred to as overhead expenses that do not vary with the level of production (e.g., barns, equipment, taxes, insurance). If no production occurs, these expenses will still be incurred. However in developing enterprise budgets, economists spread the cost of fixed expenses over time and across enterprises that use the particular input in the farming operation. In addition to accounting for variable and fixed expenses, economists also place an economic value on the land and operator labor as an opportunity cost to reflect that if the producer were not growing tobacco, the land and labor could be used for production of other crops or the labor employed in non-farming employment opportunities. Enterprise budgets are generally divided into several categories, including:

- Gross Revenue—estimated average price per pound times the expected yield per acre
- Total Variable Costs—an aggregation of all expenses that vary with the level of production
- Returns Above Variable Costs—gross revenue less total variable costs
- Total Fixed Costs—an aggregation of total overhead expenses
- Returns to Operator Labor and Management—gross revenue less total variable costs less total fixed costs
- Operator Labor—an estimated value of the operator's labor
- Returns Above All Costs—returns to operator labor and management less operator labor

The University of Kentucky's tobacco production budgets are located online at http://www.ca.uky.edu/agecon/index.php?p=29, or may be obtained at the local county Extension office. The budgets are meant to serve as a guide (not a rule) to assist producers in determining their own anticipated returns and costs of production. Growers must incorporate their own input costs into the budgets to accurately observe how sensitive economic returns are to changing yields, input costs, market prices, etc. The two factors that have the greatest effect on tobacco production costs on a per-pound basis are yield and labor.

Yield

Burley tobacco yields trended up during most of the 1960s as growers responded to the acreage program by attempting to maximize their yields on a per-acre basis. However since the adoption of the poundage program in the early 1970s, burley tobacco yields have exhibited a downward trend for a variety of reasons, including increased disease pressure and challenging

Figure 1. Distribution of burley costs.

Source: *UK Burley Budget*

Figure 2. Sensitivity of burley input cost by yield.

Source: *UK Burley Budget*

weather-related growing conditions. Over the past two decades burley tobacco yields in Kentucky averaged around 2,100 lb/A. Current budgets and price schedules indicate that 2,200 lb/A is close to the break-even yield, given an average cost structure. Obviously under the current price and cost environment, burley growers will either have to achieve yields above our historical average or find ways to reduce costs in order to survive in a more competitive market. Average yields should increase in the post-buyout era as the profit potential for relatively low-yielding producers will force many of these producers to exit. The current labor situation may cause producers to be more concerned about yield per plant than yield per acre. While yield per plant is affected by variety selection and plant population, growers should strive for around 0.33 lb of cured leaf per plant or better. Burley growers averaging 0.25 lb of cured leaf per plant (implying a yield of less than 2,000 lb/A) will find it difficult to survive in the current cost/price environment.

Dark tobacco yields have been exhibiting the opposite trend, as burley with many producers averaging well over 3,000 lb/A in recent years. Consequently, dark tobacco growers have been able to achieve 0.6 lb/plant or better given their smaller plant populations and improvement in yields per acre. Undoubtedly increasing yields, coupled with relatively smaller post-buyout price adjustments, have enabled dark tobacco production to remain profitable for most growers in the early post-buyout era.

Labor

The most challenging factor affecting most tobacco farmers today is labor. Labor-saving technologies for tobacco have been studied and implemented for decades, but tobacco still remains a very labor-intensive crop. Tobacco production studies have generally indicated that despite some gains in labor efficiency over the years, it still takes 150-200 hours of labor to grow an acre of burley tobacco, with dark tobaccos requiring 300 or more hours per acre. A lot of attention is generally focused on harvesting labor (approximately 25 to 30% of total hours hours/A), but market preparation requires the largest portion of labor hours (approximately 35 to 40% of total hours/A) in burley tobacco production. Historically, tobacco budgets have generally indicated that labor accounts for nearly 50% of production expenses for burley tobacco and over 50% for dark tobacco. However, these percentages may be conservative given the escalating cost of hired labor in recent years. Consequently growers, tobacco companies, and engineers continue to study and monitor various labor saving technologies (e.g. larger bale size, more efficient stripping systems, mechanical harvesters, alternative curing structures, varying barn designs) to enhance U.S. burley competitiveness. As with any capital investment, producers are encouraged to evaluate the additional costs versus the anticipated benefits of adopting such labor saving technologies over the expected useful life of the asset.

While the cost of labor is a major concern, a greater concern among many tobacco farmers is access to reliable labor. Due to a very limited supply of domestic laborers willing to work in tobacco, farmers have become increasingly dependent on migrant laborers, which may currently account for 75% or more of the total labor hours in tobacco production. However, immigration issues (e.g., border control of illegal labor, terrorism concerns) and competition for migrant labor from the non-farming sector has dramatically reduced the supply of seasonal workers available in recent years. Consequently, farm organizations and policy makers in tobacco-producing states have sought national immigration reform legislation that would allow for a guest worker program leading to an adequate supply of legal/affordable labor.

The Immigration Reform and Control Act authorizes the lawful admission of temporary, nonimmigrant workers (H-2A workers) to perform agricultural labor of a temporary or seasonal nature. Rules and regulations regarding the hiring of legal labor are complex but are manageable for informed growers. Some (but not all) of the major guidelines (as of February 2010) of the program are summarized below:

- All employers who hire temporary workers must file a labor certification application with the U.S. Department of Labor. An authorized agent or association may file an application on behalf of an employer.
- Employers must make an effort to hire U.S. workers and show that hiring migrant laborers will not adversely affect the wages of U.S. workers in similar positions.
- Employers must pay H-2A workers the same as U.S. workers and the wage must be the greatest of the following: the minimum wage, the adverse effect wage rate (AEWR), the prevailing hourly wage rate for a given crop/area, or the agreed-upon collective bargaining wage.
- Workers must be guaranteed employment for at least three-fourths of the hours in the work contract.
- Farmers who employ H-2A workers must provide:
  - Reimbursed transportation and subsistence expenses for all workers for their travel expenses to the United States (after completion of 50% of the contract time period), provide transportation from the employees' housing to the worksite, and travel expenses back to the worker's area of residence at the end of the work contract.
  - Free and approved housing, which will be inspected annually according to specific federal, state, and local standards and codes.
  - Either three meals a day or kitchen facilities for workers to prepare their own meals. If providing meals, the employer can deduct a federally approved amount from the employee's paycheck if outlined in the work contract.
  - A copy of the work contract or job clearance order that includes the contract period, work dates/times, job duties, rate of pay, and other significant conditions of employment.
  - Workers compensation insurance.
  - Tools and supplies to complete assigned work.
- Detailed accurate record keeping is vital to document all employment activities/issues for this program! Records must be maintained for three years.

Several fact sheets on the U.S. Department of Labor's web site are useful in understanding the basic guidelines. These include:

- H2A General Fact Sheet: http://www.dol.gov/whd/regs/compliance/whdfs26.htm
- H2A Compliance Review: http://www.dol.gov/whd/regs/compliance/fmla/H2A.htm

Other relevant employer information for the H-2A program, including a link to an online application processing system for H-2A workers, can be found at http://www.ca.uky.edu/agecon/index.php?p=258. In Kentucky, the Department for Workforce Investment: Office of Employment and Training (275 East Main Street, 2W-A, Frankfort, KY, 40601) is available to assist growers with the H-2A program. Information from this office is available online at http://oet.ky.gov, or by contacting Jeff Gatewood (Jeff.Gatewood@ky.gov) or Henry Gross (HenryC.Gross@ky.gov), or by calling 502-564-7456.

In Tennessee, the Department of Labor and Workforce Development can assist Tennessee farmers with the H-2A program. This Department can be contacted by phone at 1-800-432-2568 or online at www.tennessee.gov/labor-wfd.

Growers who plan to use migrant labor are strongly encouraged to become well-educated (either on their own or by working with a reputable labor association) on the rules and regulations of using migrant laborers. Given recent attention to illegal immigration issues nationwide, fines have increased in recent months for employing illegal workers or for not following labor/housing requirements.

Finally, concerns over the labor situation have prompted several legislative proposals in Congress. Growers are encouraged to provide input and closely monitor the situation for changes that could affect the supply of labor and the general requirements outlined above.

Selecting Burley Tobacco Varieties

Bob Pearce, Paul Denton, Andy Bailey, and Bob Miller

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 growing region. 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 varieties with little or no resistance to black shank (Figure 1). 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 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 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 (such as 2010) when weather is conducive to black shank (Table 1). In some situations, fungicides may 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 and, of course, yield and quality are important traits to look for in a variety. Many of the new black shank-resistant varieties are capable of producing high yields (Figure 1), and under high rainfall conditions can produce a large stalk diameter and heavy plants compared to

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

Table 1. Survival of selected burley tobacco varieties in fields heavily infested with race 0 and race 1 black shank (2008-10).

Variety	Black Shank (% Survival)		
	2008	2009	2010
Hybrid 404LC	7	40	3
HB 04PLC	14	22	3
KT 206LC	89	97	68
NC 7LC	54	83	16
KT 209LC	97	98	85
KY14XL8LC	5	3	0
KT 204LC	87	100	66
HP 3307PLC	69	97	49
N 7371LC	57	93	30
KT 210LC	85	93	66
NC 2002LC	11	12	0
TN 90LC	49	90	57
Seasonal Avg.	51	66	37

Figure 2. Two-year average (four locations each year) of grade Index for selected burley tobacco varieties. Grade index is a numerical ranking of quality based on the federal grading system; a higher grade index indicates better quality.

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. The higher the grade index, the higher the 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), with a range of only about 10 points on the grade index between varieties over two years of testing at four locations. Five varieties (KT 204LC, KT 206LC, TN 90LC, NC 7LC, and KY14xL8LC) 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.

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 2.

Variety Descriptions

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 on the 0-to-10 scale, which is comparable to NC 7 and KY14 x L8. Fusarium wilt is a soilborne fungal disease that is present in some tobacco producing regions of Kentucky, 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 tobacco vein mottling virus and tobacco etch virus. Yield potential, stalk size, growth habit, and maturity are similar to KT 206LC and KT 204LC. Cured leaf quality has been good in preliminary testing with this variety.

KT 209LC is a late-maturing, high-yielding variety with superior black shank resistance. It has the highest available resistance to both races of black shank. On a scale of 0 to 10, with 10 being complete resistance, it has a race 0 resistance of 10 and a race 1 resistance of 8. Note that even though the resistance to black shank is relatively high in KT 209LC, it is not immune to race 1 (Table 1). In areas with heavy race 1 black shank pressure, fungicides are still recommended for KT 209LC. (see "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 90.

KT 206LC became the most widely grown variety in only the second year following its release and it remains popular today. KT 206LC is a 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 to

race 0 of the black shank pathogen, indicating no black shank symptoms expected in fields with only race 0 and a 7 level 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. KT206LC 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 produce 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.

KT 204LC 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 206LC or 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. It is a late-maturing, high-yielding variety. KT 204LC tends to grow slow early in the season, which may discourage producers initially, but its growth in the later part of the season is impressive.

TN 90LC, a medium-late 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. Delayed topping increases sucker development and may make sucker control more difficult. KY 14 x L8LC initiates sucker growth sooner than most other varieties, making early topping a must. Best results are achieved when 14 x L8LC is harvested at 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 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 maturity, large leaves, and an average-sized stalk diameter. Cured-leaf quality is generally good. It is a good choice for growers who have no black shank and need a high-yielding variety that matures earlier than the "KT" varieties.

HB 3307PLC, a variety from F.W. Rickard Seed, is described as a medium-maturity 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 HB04P 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.

Hybrid 404LC, a relatively new release from Clay's Seed Company, 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 is a medium-maturing variety that appears to have generally good quality.

N 7371LC, released by Newton Seeds 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 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 very 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 varieities like Hybrid 404, NC 7, HB04P 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. Oth-

erwise, NC 7 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). It has some unique resistance that may not be significant in Kentucky, including resistance to root knot nematode and tobacco cyst nematode. Yields are expected be high under ideal conditions and quality is expected to be good. Avoid areas where race 1 incidence is high. NC 7 may be a good solution where Fusarium wilt incidence is high. However, if race 1 black shank pressure is also expected to be high (common in many fields around KY), KT 210LC is a better choice.

Table 2. New and selected[1] 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[2]	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[3]	10	7	R	H	R	1	9	Late
KT 209LC	10	8	R	H	R	1	9	Late
KT 210 LC	10	7	S	H	R	5	8	Late
NC BH 129	1	1	S	H	R	1	7	Med-Early
NC 3**	2	2	R	H	R	1	7	Med-Late
NC 4	2	2	R	H	R	6	5	Late
NC 5**	10	4	R	H	R	0	7	Med-Late
NC 6**	10	3	R	H	R	0	8	Med-Late
NC 7**	10	3	R	H	R	5	8	Med-Late
NC 2000[4]	0	0	S	L	R	1	4	Late
NC 2002[4]	0	0	R	M	R	0	5	Late
TN 86LC	4	4	R	H	S	0	6	Late
TN 90LC[3]	4	4	R	H	R	0	5	Med-Late
TN 97LC	4	4	R	H	R	0	6	Med-Late
HYBRID 403LC	0	0	S	M	R	6	9	Medium
HYBRID 404 LC	0	0	S*	H*	R*	-	9	Medium
HYBRID 501LC	5	5	S	H	R	4	5	Med-Early
N 126	0	0	S	M	R	3	8	Medium
N 777LC	2	2	S	M	S	0	3	Med-Late
N 7371LC	4*	4*	-	-	-	-	7*	Late
NBH 98	2	2	S	M	R	3	5	Medium
HB04PLC	0	0	S	H	R	0	9	Medium
HB3307PLC	10*	4*	R*	H*	S	-	8*	Medium
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

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

Choosing Dark Varieties for 2011

Andy Bailey and Bob Miller

Factors to consider when selecting a dark tobacco variety include resistance to black shank and other diseases, quality, maturity and holdability, and yield potential. Handling characteristics like stalk diameter and growth habit may also be important. Maturity, holdability after topping, and performance for early and late transplanting are especially important when selecting varieties for double crop fire-curing. Growers should be sure to adhere to contract specifications for use of screened or LC varieties, and some buyers may even specify which varieties to use.

Resistance to black shank may be the most important factor for many dark growers. No dark variety has black shank resistance that is comparable to many modern burley varieties. Levels of race 1 black shank are increasing throughout the dark tobacco region, and varieties with at least some resistance to race 1 black shank should be considered for use in fields where black shank is known to exist. The use of fungicides is 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 two years of grass is recommended for dark tobacco. Dark tobacco should not be grown in the same field for two consecutive years, regardless of variety.

Agronomic characteristics of dark tobacco varieties may vary between years and locations. 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. Yield potentials listed are an average yield across several trials and seasons and actual yields may vary from those listed. The disease resistance indicated can be expected if disease pressure is present.

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 potential (3,000 lb/A) and 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 that are similar to the Madoles. Little Crittenden has no disease resistance.

Narrowleaf Madole LC is still one of the most popular dark tobacco varieties grown. It can be used as a fire-cured or air-cured variety and has medium-late maturity with excellent yield (3,200 lb/A) and cured leaf quality. It is known for its excellent curing characteristics. Narrowleaf Madole has a very prostrate growth habit with long, drooping leaves and a smooth leaf texture. Narrowleaf Madole 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 has no disease resistance.

TR Madole is typically used as a fire-cured variety. It has early to medium maturity and good yield (3,200 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 smooth leaf surface, which makes it well suited to cigar-wrapper style markets. TR Madole 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 an 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 very 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, is the only dark variety with known resistance to Fusarium wilt, and performs better than many other varieties when transplanted early (prior to May 15). KY 171 has been 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 typically used as a 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 Madoles but has a larger stalk size than most other dark tobacco varieties. Cured leaf quality is typically lower than most other varieties, as the leaf face tends to cure to a dark brown, while the back of the leaf cures to a light tan. DF 911 has high resistance to black root rot, wildfire, and tobacco mosaic virus.

DT 538LC was developed by Newton Seed and is typically used as a fire-cured variety but may also work well as an air-cured variety. It has excellent yield (3,400 lb/A) and fair cured leaf quality. It has perhaps the best combination of race 0 and race 1 black shank resistance of any dark variety currently available, with resistance rated slightly higher than KT D4LC or KT D8LC. It has medium maturity with a semi-erect growth habit and fairly coarse leaf texture.

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. Smooth leaf texture properties have made VA 309 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 can be used as an air-cured or fire-cured variety. It has early to medium maturity and good yield potential (3,100 lb/A). It has an erect growth habit, with 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 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 firing 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, KT D4LC, 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 developed as a fire-cured variety but has also performed relatively well as an air-cured variety. KT D4LC may have only fair cured leaf quality but has the highest yield potential of any dark tobacco variety currently available (3,600 lb/A). It has a very erect growth habit, with medium maturity and leaves light in color that are similar to VA 359. Spacing between leaves is closer than most other varieties and it typically will have three to four more leaves than other varieties topped to the same height on the stalk. It has a coarse leaf texture with cured leaf quality that is usually lower than most other varieties. It has medium resistance to race 0 and race 1 black shank but

Table 1. Characteristics of dark tobacco varieties.

Variety	Maturity	Black Shank (0-10)[a] Race 0	Black Shank (0-10)[a] Race 1	Use[b]	Relative Yield Score[c]	Relative Quality Score[c]	Black Root Rot	TMV[d]	Wildfire
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
DF 911	Medium	0	0	F	8	6	High	High	High
KY 160	Medium	0	0	A	3	9	None	High	None
KY 171[e]	Medium	0	0	A/F	7	7	High	High	None
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 D4 LC	Medium	4	4	F/A	9	5	None	None	None
KT D6 LC	Early-Med	3	3	F	8	7	High	High	High
KT D8LC	Medium	4	4	F/A	9	5	None	None	None
DT 538 LC	Medium	4	4	F/A	8	6	High	-	-
PD 7312 LC	Medium	0	0	F/A	7	8	High	High	None
PD 7302LC	Medium	10	0	F/A	6	7	High	High	-
PD 7309LC	Medium	10	0	F/A	7	8	None	None	-
PD 7318LC	Medium	10	0	F/A	8	7	High	High	-
PD 7305LC	Early	10	3	F	8	6	High	High	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 has medium resistance to Fusarium wilt.

Table 2. Yield and quality grade index* for 2008-2009 dark fire-cured variety trials at Princeton and Murray, KY, and Springfield, TN.

Variety	Princeton KY Yield (lb/A)	Princeton KY Quality Grade Index	Murray KY Yield (lb/A)	Murray KY Quality Grade Index	Springfield TN Yield (lb/A)	Springfield TN Quality Grade Index	Average Yield (lb/A)	Average Quality Grade Index
NLMadole LC	3007	59.6	3127	58.6	3236	60.4	3123	59.5
TR Madole	3039	36.1	3001	41.0	3560	56.5	3200	44.5
KY 171	3072	53.9	3069	47.9	3285	48.3	3142	50.0
VA 309	2822	40.6	2919	46.2	3215	46.5	2985	44.4
DT 538LC	3095	51.5	3125	36.7	3364	63.0	3195	50.4
KT D4LC	3113	44.9	3613	51.4	3583	45.2	3436	47.2
KT D6LC	3235	49.3	3534	50.3	3320	56.6	3363	52.1
KT D8LC	3296	42.0	3535	48.1	3573	50.5	3468	46.9
PD 7312LC	3111	60.7	2941	57.1	3135	66.2	3063	61.3
PD 7302LC	3005	56.2	2913	50.1	2995	52.4	2971	52.9
PD 7309LC	2747	62.4	2952	57.8	3345	57.1	3014	59.1
PD 7318LC	3133	56.3	3131	59.9	3306	43.1	3190	53.1

**Quality grade index is a 0-100 numerical representation of Federal Grade received and is a weighted average of all stalk positions.*

may be slightly lower than DT 538LC. KT D4LC has no resistance to black root rot, tobacco mosaic virus, or wildfire.

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 D4LC or TN D950. It has good resistance to race 0 and race 1 black shank (medium, but slightly lower than KT D4LC or DT538LC), 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 more like TN D950, with rapid leaf maturity occurring at about five weeks after topping.

KT D8LC is very similar to KT D4LC and will perform well as a fire-cured variety and may be a better air-cured variety than KT D4LC. KT D8LC has the same disease resistance package as KT D4LC, with 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 a very erect growth habit with medium maturity. Other characteristics such as leaf number, color, texture, and leaf quality for KT D8LC are very similar to KT D4LC. KT D8LC has excellent yield potential (3,500 lb/A).

PD 7312LC is a hybrid of KY 171 x Narrowleaf Madole developed by Rickard Seed. It has medium maturity, excellent yield (3,200 lb/A), and very good cured leaf quality. PD 7312LC can be used as a fire-cured or air-cured variety. It performs well as an early-transplanted variety (prior to May 15), so it has been a good choice for early-transplanted first cures for double-crop fire curing, provided black shank is not a concern. It has high resistance to black root rot and tobacco mosaic virus and medium resistance to Fusarium wilt but no black shank resistance.

PD 7302LC is a hybrid developed by 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. 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 excellent 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 0 black shank may exist.

PD 7309LC is another hybrid developed by 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.

Table 3. Yield and quality grade index[a] for 2008-2009 dark air-cured variety trials at Princeton, KY and Springfield, TN.

	Princeton KY		Springfield TN		Average	
Variety	**Yield (lb/A)**	**Quality Grade Index**	**Yield (lb/A)**	**Quality Grade Index**	**Yield (lb/A)**	**Quality Grade Index**
NL Madole LC	2512	35.0	3090	36.2	2801	35.6
Lit Crittenden	2479	29.7	2754	39.2	2617	29.5
KY 171	2576	31.4	2955	29.0	2766	30.2
VA 359	2544	27.8	2896	22.3	2720	25.1
DT 538LC	2651	20.6	3092	22.2	2872	21.4
KT D4LC	2784	19.3	3213	19.0	2999	19.2
KT D6LC	2968	22.6	3190	22.7	3079	22.7
KT D8LC	2706	26.1	3246	22.5	2976	24.3
PD 7312LC	2810	27.5	3063	35.0	2937	31.3
PD 7302LC	2522	26.5	2682	37.2	2602	31.9
PD 7309LC	2387	28.4	2791	46.4	2589	37.4
PD 7318LC[b]	2618	42.8	2663	34.7	2641	38.8

a Quality grade index is a 0-100 numerical representation of Federal Grade received and is a weighted average of all stalk positions.
b Data for PD 7318LC only available from 2009.

PD 7318LC is a hybrid introduced in 2009 by Rickard Seed. PD 7318LC is very similar to PD 7309LC in growth habit and also 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 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. PD 7318LC may also be a good choice for early transplanted first cures in double crop, fire-cured tobacco where race 0 black shank may exist. Stalk size of PD 7318LC may be slightly larger than many other dark varieties, although not as large as DF 911.

PD 7305LC is a hybrid released by 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 very good yield potential (3,100 lb/A). 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. 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. PD 7305LC may also be a good choice for first cures transplanted in early May for double-crop curing.

Management of Tobacco Float Systems

Bob Pearce, Andy Bailey, Kenny Seebold, and Lee Townsend

What is the value of a tobacco transplant? The typical market value of finished transplants is in the range of $42 to $45/1,000 plants. However, 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.

Most tobacco growers have the knowledge and skills necessary to grow good quality transplants, but many do not have the time to do the job right. For some, 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 transplants over long distances involves risk. Transplants may be infected with a disease even though they appear healthy at the time of delivery. One example of this principle is the potential for blue mold on transplants grown in the Deep South. Blue mold does not overwinter in Kentucky or Tennessee and is typically spread into our area on wind currents from the southwest. When infected transplants are brought in, blue mold "hot spots" can develop rapidly and greatly accelerate the problem, costing growers money in lost production and increased control measures. 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, or buy plants produced in areas north of Kentucky (where blue mold is unlikely to be present).

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.

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*

Tray Selection

Most trays used in tobacco float systems are made of polystyrene, 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.

Some trays have been described as "glazed"; these trays have been manufactured by a process that seals the inner surfaces of the cells. Data from greenhouse trials with new trays have shown little difference in transplant production in glazed and unglazed trays (Table 2), although glazed trays may be slightly easier to clean and sanitize due to the sealed surface in contact with the plant roots.

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.

Table 2. Greenhouse performance of float trays.

Tray type	Dry Cells (%)	Germination (%)	Spiral Root (%)	Usable Plants (%)
2004 data				
Regular	--	96.0	6.1	89.8
"Glazed"	--	96.5	6.1	91.0
LSD 0.05*		NS	NS	1.1
2006 data				
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.*

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 generally 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 to be used.

Some float-plant 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 feet.

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 of trays is not recommended, as this can result in the production of noxious smoke. Disposing of used trays in an approved landfill is perhaps the best option if polystyrene trays are allowed.

Tray Sanitation and Care

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 of trays is difficult because of the porous nature of polystyrene. As the trays age, they become 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.

Common soil inhabitants and field pathogens are two types of organisms 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 be contaminated. Trays should be rinsed off immediately after transplanting to remove any media, plant debris, or field soil.

The surest way to reduce the risk of diseases carried over in trays is to purchase new trays each season. However, previously-used trays may be reused after disinfecting 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 in a greenhouse, where UV light and heat will cause deterioration and damage. If trays have been sanitized before storage, store them in such a way as to avoid recontamination. Take appropriate steps to protect trays from damage due to nesting of small rodents and birds.

Steam, chlorine bleach, and quaternary ammonium chloride salts are available disinfectants. None of these disinfectants has been totally effective in killing all the pathogens. Each has positive and negative points, as discussed below.

Kentucky research has found steam to be the most effective disinfectant. It consistently does the best job of killing the range of pathogens found in Kentucky. Steam sterilization of trays is especially recommended for commercial transplant producers. Steaming at 170-180°F for 30 minutes has been successful, but lower temperatures and longer times may also be used. The cost of using steam to sterilize trays, however, is high and some trays will be damaged by steaming. Thus, the biggest problem with steaming at the farm level is insufficient control of temperature for the prescribed period of time without damaging the trays.

Chlorine bleach solutions have given a high level of control, but, overall are not as effective as steam. Research has shown little benefit of using more than 1 part bleach to 9 parts water (10% solution). Any commercially available bleach can be used to make the sterilizing solution, but avoid concentrated formulations. Industrial-type bleaches cost more and don't add any additional benefit. Bleaches work best when the trays are washed with soapy water, dipped several times into clean 10% solution, and covered with a tarp to keep them wet with the bleaching solution overnight. Afterwards, the bleach solution should be washed from the trays with clean water or water plus a quaternary ammonium chloride salts product, as listed below, followed by aeration to eliminate the chlorine and salts of chlorine. Without proper aeration and post-washes, salt residues can cause serious problems, especially with older trays that tend to soak up more materials. Worker safety issues are also important with bleach. It is critical that the bleach solution remain below pH 6.8. Also, because organic matter deactivates bleach quickly, a new solution should be made up every two hours or whenever it becomes dirty, whichever comes first.

Quaternary ammonium chloride salts are marketed under such trade names as Greenshield, Physan, and Prevent as solutions containing 20% ammonium chloride. While many growers use them, our tests indicate that they are not as effective as some believe. Their greatest benefit is in the final wash and on exposed surfaces in the greenhouse. In all our tests, they have always provided some control as compared to using soap washes only, but they have always been inferior to any of the above-mentioned methods.

Water Quality

Water quality for tobacco float plants has not been a big problem in Kentucky or Tennessee when using a fertilizer that is well suited for the float system. However, there are a few things to keep in mind. Never use untreated surface water for tobacco float beds. Surface water may contain high levels of disease-causing organisms. 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, with about 15-20% of the wells tested in Kentucky requiring the addition of acid to reduce the alkalinity to a manageable range for float plant production. Rarely are there cases where water quality problems are severe enough to warrant switching to a different water source. 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 microsiemens/centimeter (µs/cm) or alkalinity above 180 ppm suggest the need for a complete water analysis. For more information on water quality for float beds, see Kentucky Cooperative Extension publication AGR-164, *Water Quality Guidelines for Tobacco Float Systems.*

Media Selection and Tray Filling and Seeding

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 the 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.

Careful attention to tray-filling procedures will minimize the occurrence of dry cells and spiral roots. 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, 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 a plug of 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 qt of water to each bag of media prior to tray filling. Wait 24 hours, if possible, to allow time for moisture to adjust evenly.

Each year there are a few cases in which large groups of trays fail to wick up after a reasonable period of time. Many of these cases 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 qt of water per bag at least a day before seeding. It is also a good idea to record the lot numbers (if legible) off any bags of media used, as they 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.

"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. Table 4 shows the influence of variety and seed source on spiral root occurrence in dark tobacco. Similar results have been observed in burley tobacco, with the variety KY14 x L8 having a higher incidence of spiral root than other varieties.

Figure 1. Spiral root of a burley tobacco transplant.

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 a problem that results in a significant reduction in usable plants. To minimize spiral rooting, 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.

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

	Usable Plants (%)		
Brand of Media	**2010**	**2009**	**2008**
Burley Gold	88.5	82.9	93.4
Carolina Choice	87.6	87.5	93.1
Carolina Silver	--	--	92.1
Premier Promix TA	81.8	88.2	94.2
Metromix Ag-lite	89.2	91.4	94.8
Southern States	90.6	90.8	91.5
Southern States w coir	79.9	89.4	--
Speedling fortified	90.2	92.2	94.7
Speedling Peat-Lite	87.2	--	92.1
Sunshine LT-5	85.2	90.3	91.1
LSD 0.05*	4.70	3.5	2.7

* *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.*

Table 4. Effect of seed source and variety on spiral rooting at 21 days after seeding, 2006 and 2007.

		% Spiral Rooting	
Seed Source	**Variety**	**2006**	**2007**
Rickard	NL Madole	11.2	6.4
Rickard	KY 171	1.0	0.5
Rickard	KT D4LC	4.3	1.8
Workman	NL Madole	5.4	4.2
Workman	KY 171	1.4	0.7
Workman	KT D4LC	4.4	1.4
Newton	NL Madole	4.9	5.7
Newton	KY 171	2.0	1.5
Newton	KT D4LC	2.6	1.1
LSD 0.05*		2.5	2.6

* *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.*

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 ½- to ¾-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 that 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 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.

If spiral root is 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 a bump on 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, due most likely to the shaking of the tray while transporting.

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 is 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.

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, 15-5-15, 20-5-20, 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.

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 salts damage to young seedlings. 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. 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.

Overfertilization 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 lb of 20-10-20 or 5.6 lb of 15-5-15/1,000 gal 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. Underfertilized plants grow more slowly and are more susceptible to diseases such as target spot.

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 be used for calibration, so read the instructions carefully. 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 µs/cm before fertilization. However, salt levels above 0.9 µs/cm may become too salty for optimum plant growth after fertilizing. Older meters may read in 100 µS/cm, and therefore would read between 1.0 and 5.0 100 µS/cm. Meters that read in ppm dissolved solids are discouraged due to difficulty in determining the corresponding increase expected after fertilizing.

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 units 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 units 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 overfertilization. Many water-soluble fertilizers now have charts on the label to help with interpretation of conductivity readings.

Climate Control

Temperature Management

Pelleted seeds germinate best around 70 to 75°F. However, a fluctuation from cool nighttime temperatures and warm daytime temperatures may be beneficial for optimum plant growth. While cooler temperatures tend to slow germination and growth, higher temperatures are risky. Temperatures that exceed 90°F may prevent or cause uneven germination and predispose plants to cold damage. 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. Temperature 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.

Cold damage can result when plants that have been exposed to high temperatures are then exposed to cooler air. Symptoms of cold damage 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. Once the bud has been damaged, it 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. Maintaining an even temperature that doesn't fluctuate too drastically can help reduce ground sucker problems. In severe cases plants may produce ground suckers that are not suppressed and grow into multiple stalks from a single plant. Such plants will be difficult to harvest and produce low yield and poor quality tobacco.

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 Kentucky and Tennessee should have enough fan power to exchange ¾ to 1 times the volume of air in a greenhouse per minute. Two fans allow for the fans to be staged so that the first 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 1¼ to 1½ times the size of the fan. Motorized shutters are best and should be on a thermostat set at a 2-3 degrees cooler setting than the fans so that they open before the fans. Alternatively, fans may be set on a 8- to 10-sec delay, which will accomplish the same thing. To reduce cold injury damage, locate fans and shutters at least 3 ft above plant levels to minimize drafts and improve 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 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 sunny day. If no one is available to make sure 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. Many greenhouses have both fans and curtains, which offers the most control of the growing environment. A side curtain should, at its maximum, provide one foot of vertical opening per 10 ft of greenhouse width. A typical 36-ft-wide greenhouse may have only 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 open to 3½ to 4 ft to meet the required guideline for ventilation.

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

Humidity Management

Humidity can cause numerous problems inside a greenhouse or float system. As the warm, moist air comes in contact with cool surfaces such as greenhouse plastic, support pipes, and float bed covers, it condenses as droplets that can dislodge and fall to the trays, disturbing seeds and seedlings and knocking soil out of cells, which results in stand loss. Some foliar diseases may be favored by high humidity. 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.

Excessive humidity is more common in greenhouses than in outdoor float beds due to more ventilation in outdoor beds. 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 or LP gas. Nonvented 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 nonvented heating systems but is also a good idea for vented systems.

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 manually pushes warm, humid air out, replacing it with cooler, less humid air. The exchange of air can reduce problems that tend to escalate during the cooler part of the day. This process will take only a few minutes of fan time to complete, but producers are reluctant to use this method due to the cost of reheating the cooler air. The benefits

can 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.

An exchange of air at daybreak can be used in combination with the exchange at night. Ventilation at this time is almost essential. Fans are safer than side curtains due to possible cold injury from side curtains. Fans should be switched on manually for a few minutes. If only one of two fans is used for this procedure, more time may be needed. As cooler air enters the greenhouse and comes in contact with the warm moist air, fog may form but should dissipate quickly. Once the humid air has been exchanged, the fans should be switched off and set to come on automatically when the air temperature reaches a set point. Later in the day when outside temperatures rise, side curtains, if available, can be lowered to improve ventilation.

Other methods may be used to protect plants from the 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 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 plant from dripping. With this method three common problems occur (1) the plants get too hot, (2) they 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. Some growers with outside beds have taped vinyl corner molding to the underside of their bows to help channel condensation away from the trays.

Circulation Fans

Circulation fans are primarily designed for one purpose, to circulate heat and air, preventing formation of hot and cold zones that could influence plant growth in the zones. Circulations fans should be located approximately 40-50 ft apart, one-fourth of the house width from each side wall, and halfway between plant level and the roof. If the fan has a slight downward angle, it will improve air circulation near the plant. Fans pointed down at too sharp an angle can increase evaporation on the tray surface and might potentially increase salt accumulation at the soil surface, affecting germination and plant growth. An elliptical pattern across several trays and in front of a fan is generally an indication that a circulation fan is positioned at too steep an angle.

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, nor does it contribute to early blooming or ground sucker formation.

The first clipping is usually the most beneficial, and direct-seeded float plants should be clipped the first time when the plant buds are approximately 1.5-2 inches above the tray surface. The first clipping should remove approximately ½-1 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. At each clipping, remove no more than ½ - 1 inch of leaf material. Three to five clippings may be necessary to achieve the best plant quality. Seldom are more than five clippings necessary. However, plants produced in trays with smaller cells (338) may require more clipping. Plants that need to be held for some length of time before transplanting can be clipped an additional time 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 plugs apply to direct-seeded plants. Plugged plants should only require two or three clippings unless setting is delayed.

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

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 for disease. 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 well away from the greenhouse to prevent disease development that could spread to healthy plants in the float bed. 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.

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 reduce the likelihood that they will cause economic loss. In addition to

disinfection of trays, a good sanitation program includes removing weeds from around the bed area and cleaning of equipment used in and around the beds. Locate the float site away from tobacco fields, barns, and stripping rooms to reduce the chance of carrying disease over from one crop year to the next.

Pesticides are available to manage certain pests in the float system; however, options are limited compared to what may be used in field production of tobacco. Chemicals that are labeled have specific instructions concerning the contamination of float water, which limits the chemical options available for controlling diseases and insects in these systems.

Management of Insect Pests

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

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 (⅛ inch) black flies with long legs and antennae, tiny heads, and one pair of clear wings. Females lay tiny ribbons of tiny, 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 can be seen resting on plant foliage or most any surface in the production facility. The shore fly's life cycle is similar to that of the fungus gnat. The maggotlike yellow to brown larva is up to ¼-inch long and has no apparent 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 bottoms of float trays but 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, mosquito dunks or granules containing Bt-i (*Bacillus thuringiensis israelensis*) should be added according to label directions.

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 in the float bed. Use empty trays to fill the bed so open water is not available, which will reduce egglaying by mosquitoes and gnats.

Regularly clip grass along bed margins so these areas can dry quickly.

Excessively wet media in trays are attractive to fungus gnats. Algal growth on the surface will attract shore flies. Keep moisture content optimum for plant growth but not above optimum 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 manage slugs before they get to the trays. Insecticides are not effective against slugs.

Cutworms

The variegated cutworm causes serious problems some greenhouse or float systems almost every year. The adult (a moth) flies in mid-March and lay 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.

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 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 body protects 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, 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.

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 transplant. Infestations start as winged aphids settle on plants and begin to deposit small numbers of live young. The initial infestation consists of a few aphids on scattered plants, but these insects are fast reproducers and numbers can increase rapidly.

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

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

Thrips

Thrips are slender, tiny (1/25 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.

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.

Prevention of infestations through the use of screens on ventilators, inspection of new material entering the greenhouse, and weed control in the greenhouse will help to manage thrips.

Cultural Controls are Essential

Cultural controls are the primary defense against 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.
- Eliminate pools of standing water on floors. Algal and moss growth in these areas can be sources of fungus gnat and shore fly problems.
- Dispose of trash, boards, and old plant debris in the area.
- Remove all plants and any plant debris; clean the greenhouse thoroughly after each production cycle.
- If possible, allow greenhouse to freeze in winter to eliminate tender insects like whiteflies.
- Avoid overwatering and promote good ventilation to minimize wet areas conducive to fly breeding.

Management of Diseases

General Information

The introduction of the float system revolutionized tobacco transplant production. The float system offers a number of advantages over the traditional plant bed but also creates ideal conditions for some important diseases of tobacco transplants. High moisture in this virtually hydroponic system favors infection of roots and leaves by a number of plant pathogens, as does the dense plant population.

Prevention is the most important part of disease management in tobacco float beds or any other production system, for that matter. We put more emphasis on prevention in the float system, however, because of its disease-conducive environment and the relative lack of fungicide tools that can be used to prevent disease or slow disease spread once it begins.

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. 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 control of diseases commonly encountered in the float system. Tables of recommended fungicides (Table 5) and relative effectiveness of cultural chemical practices against common diseases (Table 6) have been included at the end of this section.

Exclude Pathogens from Transplant Facilities

Avoid the introduction of plant pathogens into the float system. Water from ponds or creeks can harbor fungi like *Pythium* or the black shank pathogen that can wreak havoc in the float system. Keep soil out of float bays—this can also cause pathogens such as *Pythium* to be introduced into the system. Keep trays out of contact with soil as well. Control weeds in and around the greenhouse or outdoor bed, since these can harbor a number of plant pathogens that can move, on the air or by insects, onto tobacco seedlings. If purchasing plugs (plug-and-transfer system), consider plants from a local or northern source. Southern-produced plugs are at risk for exposure to the blue mold pathogen in areas where they are grown and have been linked to serious outbreaks of blue mold in previous seasons (2006, for example). These same considerations are valid if you are buying finished plants to set in the field. Do not grow transplants near vegetable fields, and do not grow ornamentals or vegetables in the same facilities where tobacco seedlings are being produced. Ornamentals and vegetables can harbor pathogens that can attack tobacco.

Make Sanitation a Routine Practice

Sanitize old trays as recommended or use new trays. New trays will all but eliminate carrying diseases over between crops of transplants. New trays will not harbor plant pathogens, but re-used trays pose more of a risk, and this risk increases as trays age. There is no guaranteed, foolproof way to sanitize used trays; however, we do have methods that will significantly reduce survival of plant pathogens on trays. Refer to the section on tray sanitation for more information. Dispose of unused or diseased plants promptly and properly. Destroy unwanted plants or place them in cull piles located at least 100 yards from float beds or tobacco fields, especially important in the management of Sclerotinia collar rot. Remove clippings and debris to prevent buildup of material that can favor development of collar rot or black leg (bacterial soft rot). Don't mow plants if diseases such as black leg are active, as this will spread disease from infected to healthy seedlings. If blue mold is found in float beds, destroy all plants immediately, even if only a small number actually show symptoms of disease. Plants with no symptoms in float beds where sporulating plants are found are likely infected with the blue mold pathogen but have yet to develop symptoms. Given time, disease will develop on these plants as well. Sanitize equipment (mowers, for example), tools, and other items (shoes, hands) that will come into contact with plants or float water. Use a 10% bleach solution for equipment and shoes, and antimicrobial soap for hands to prevent the introduction of pathogens.

Create an Unfavorable Environment for Plant Pathogens

Maintain good air movement through the use of side vents and fans, and keep water levels high enough for float trays to clear the side boards of the bays, which allows for better movement of air (water level may be kept low initially when plants are small to prevent cold injury and raised as plants grow). Long periods of leaf wetness favor most diseases encountered in the float system. Good airflow promotes rapid drying of

Table 5. Guide to chemicals available for control of tobacco diseases 2009—transplant production.

Product(s)	Product Rate Per Application[a]	Product Rate Per Season	Target Diseases	Label Notes
Agricultural Streptomycin(Agri-Mycin 17, Firewall)	100-200 ppm (1-2 tsp/gal H_2O)	no limit	wildfireblue 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(Dithane DF, Manzate ProStick, Penncozeb)	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			
Terramaster 4 EC	1.0-1.4 fl oz/100 gal H_2O	2.8 fl oz	damping-off (*Pythium* spp.) root rot (*Pythium* spp.)	Apply to float-bed water no earlier than 2 weeks after seeding. Additional applications can be made at 3-week intervals. Use high rate for curative treatments; begin high rate no sooner than 3 weeks after seeding. Do not apply later than 8 weeks after seeding.

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

Table 6. 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	-	+	+++	+	+++	+++	+++	+++	+++	+++	-	-
Fungicides[b]	+++	+++	++	++	-	++	+	++	+	+	-	+
Maintain proper fertility[c]	+	++	+++	+	++	+	+++	+	+	+	-	+++
Temperature control	+	+	++	+	+	+	++	++	+	+	-	+
Minimize splashing	-	+	++	+	-	-	++	+++	+	++	-	-
Proper clipping[d]	-	-	++	+	++	+	++	++	+	+	-	-
Avoid buildup of leaf clippings in trays	-	+	+	++	++	-	++	+	++	-	-	-
Dispose of diseased plants properly	-	-	+	+	++	++	++	+	+	+	-	-
Weed control in/around float system	-	-	+	+	+	-	++	++	+	++	++	-
Insect control	-	-	-	-	-	-	+	+	+	-	++	+
Avoid out-of-state transplants	-	-	-	-	-	+++	-	-	-	-	+	-
Avoid tobacco use when handling plants	-	-	-	-	-	-	-	-	-	-	++	-

[a] *- = no effect on disease management, + = minimally effective, ++ = moderately effective, +++ = highly effective.*
[b] *Preventive applications only (made before symptoms appear).*
[c] *Based upon a recommended range of 75-100 ppm of nitrogen.*
[d] *Clip using a well-sharpened blade under conditions that promote rapid drying of foliage.*

foliage, creating less favorable conditions for diseases such as target spot, collar rot, blue mold, and black leg. Minimize the potential for water to splash between trays. Avoid overhead irrigation, fix leaks in roofs, and apply fungicides early in the day so that foliage dries quickly. Temperature control is critical as well—excess heat can lead to problems with target spot and black leg, while cooler temperatures favor collar rot and blue mold. Don't overpack media into cells when seeding, as this leads to excessively wet conditions in the tray, favoring the development of disease. Older trays tend to water-log easily, causing media to become saturated. Trays with high cell counts (338) not only require more management, but the dense foliage may favor disease development.

Minimize Plant Stress

Keep your transplants as stress-free as possible. Avoid temperature extremes, and keep fertilizer levels within recommended ranges. Plants that are underfertilized or overfertilized are more susceptible to diseases in general. For example, target spot is much more likely to develop if nitrogen levels are below 50 ppm for extended periods of time, while black leg is generally seen when nitrogen is consistently above 150 ppm. Excess nitrogen also leads to rapid, rank growth of transplants. New, succulent growth is more disease-prone and also takes longer to dry out. When clipping plants, avoid the buildup of leaf matter on float trays. Some pathogens, particularly *Sclerotinia* and bacteria that cause soft rots and black leg, can use leaf debris as a food base to become established and then spread in the float system. Clip properly (see section on clipping) to minimize stress and also the volume of clippings, and use a well-sharpened blade to promote rapid healing of wounds. Make sure that plants dry quickly after mowing.

Apply Fungicides Wisely

Relatively few fungicide products are labeled for use on tobacco in the float system, and only Pythium root rot, blue mold, and target spot/damping-off are targeted by these materials. The remaining diseases can be managed only by cultural practices.

Fungicides can be effective in a disease management program, but applications must be made in a timely way for best results. For example, it is possible to get good-to-excellent control of Pythium root rot with Terramaster 4EC, but only if the material is applied preventively. Make the first application two to three weeks after seeding or when roots first enter the water. A second treatment can be made three weeks after the first, and a final application (if needed) can be made two weeks after the second treatment. Do not apply Terramaster later than eight weeks after seeding; make sure that the product is mixed thoroughly in float bays to minimize the risk of phytotoxicity. "Rescue" applications of Terramaster (see Table 5 for rates) in systems with active PRR will halt further development of disease, and symptomatic seedlings will likely recover. However, the higher rates of Terramaster used in rescue treatments increase the risk of phytotoxicity. In addition, recuperating plants may still harbor Pythium, which can weaken them and neighboring plants later in the season (and increase their susceptibility to

black shank and Fusarium wilt). 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 if 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.

Mancozeb (Dithane DF, Manzate, and Penncozeb) is a widely used fungicide that is labeled for target spot, damping-off (Rhizoctonia), and blue mold. Mancozeb provides reasonable control of target spot, and because it is a protectant-type fungicide (not systemic and has no curative activity), it should be applied at the first signs of disease at the latest (see Table 5 for rates). Use 3 gal of spray material per 1,000 sq ft, applied as a fine spray to improve coverage. Apply while plants are small, and increase spray amount gradually to 6-12 gal as plants grow to transplantable size. Be sure sufficient water is used to wet the base of the stems with runoff to increase the control potential for damping off. Avoid contamination of the float water during treatment. Do not apply this fungicide to plants smaller than dime size to avoid damage. Producers with a history of problems with target spot should consider routine application of mancozeb, beginning when plants are dime-sized and continuing on a five- to 10-day schedule, depending upon age of transplants and weather conditions. For control of blue mold, mancozeb must be in place before plants become infected. Because of the fast-moving, explosive nature of blue mold in the float system, applications made after the first signs of disease have little chance slowing the disease down to manageable levels. Consult with your county Extension office, local press and radio, or university Extension specialists for guidance on when to treat for blue mold. You can also visit the Kentucky Tobacco Disease Information Page (http://www.uky.edu/Ag/kpn/kyblue/kyblue.htm) or the North American Plant Disease Forecast Center (http://www.ces.ncsu.edu/depts/pp/bluemold) for up-to-the-minute reports on blue mold and other diseases. Apply mancozeb more frequently to rapidly growing plants if conditions are warm, humid, and overcast or if target spot is present.

Other products that can be used in the float system include Aliette WDG (blue mold), agricultural streptomycin (blue mold, angular leaf spot/wildfire), and milk (tobacco mosaic virus). Apply Aliette or streptomycin to plants dime-sized or larger in a manner similar to Dithane DF (see Table 5 for rates). Do not allow either Aliette or streptomycin to contaminate float water, as serious injury to plants can occur. Keep in mind, too, that products that specifically prohibit use in greenhouses cannot be applied to tobacco in the float system, since the EPA considers float beds to be mini-greenhouses. Only products labeled for tobacco can be used—do not apply to tobacco products intended for greenhouse ornamentals or bedding plants. Producers can use existing stocks of materials that are no longer labeled for tobacco (Ferbam Granuflo, Carbamate, Terramaster 35WP) so long as the grower has a copy of the original product label. Follow all label directions, and take special care to protect workers from exposure to pesticides.

Develop an Integrated Plan to Manage Diseases

Disease-free transplants pay dividends down the road 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.

Special Considerations for Outside Direct-Seeded Float Beds

Production of tobacco transplants in outside direct- seeded beds is inherently more risky than greenhouse production or plug and transfer. 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 x 6's or 2 x 8's is sufficient to construct a float bed. Most float trays are slightly smaller than 14 x 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. Any extra space that must be left, as open water will only lead to increased algae growth.

Six-mil plastic is more forgiving and preferred over thinner plastic. The plastic should be draped over the framing 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 can fall below outside temperature inside the beds 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 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 left on for an extended period of time during rainy weather can cause plants to stretch. Once plants stretch, they will not recover.

Plugged plants and 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, Tillage, and Fertilization

Bob Pearce, Paul Denton, and Greg Schwab

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, 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, and proximity to curing facilities or irrigation.

The roots of a tobacco plant are very sensitive to the aeration conditions in the soil. In saturated soils, tobacco roots begin to die within six to eight hours, with significant root loss occurring in as little as 12 to 24 hours. This sensitivity to aeration conditions is why tobacco plants "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 Kentucky and Tennessee. The best soils for burley and dark tobacco production tend to be well-structured silt loam or silty clay loam soils.

Tobacco can be produced successfully on heavier soils and somewhat poorly drained soils, but extra precautions are needed to avoid compaction. Such soils generally warm up and dry out much more slowly in the spring, so planting often must be delayed. Soils with a high clay content should not be tilled when wet in order to avoid creating compaction and further reductions in drainage.

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 leading to declining productivity over time. Rotation planning includes cover crops between tobacco crops, and in some years, other crops grown in place of tobacco.

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 crops reduces oxygen in the root zone and may result in the production of organic compounds 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. They do not produce as much growth in the fall but have the potential to supply additional nitrogen. In practice, the amount of nitrogen contributed by legume cover crops has been found to be relatively small because they typically scavenge remaining N from the tobacco crop rather than fixing N from the atmosphere.

The benefit of crop rotation for reducing certain diseases is well known (see *Pest Management* section); however, rotation also has significant agronomic benefits. The ideal rotation for tobacco in Kentucky and Tennessee 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 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 very beneficial from a disease standpoint and at least slow the degradation of soil structure compared to continuous tobacco production. Some rotation, even if it is short, is better than no rotation.

Rotation to other row crops such as corn or soybean can also be beneficial to tobacco, but less so than a rotation which includes sod crops. In row-crop rotations, precautions should be observed to minimize the potential carryover of herbicides and adhere to rotational guidelines on pesticide labels. A reduction in corn yields following tobacco has been reported

by some growers. Herbicide carryover has also become an increasing concern in rotations with sod in recent years, with the introduction of a number of pasture herbicides containing picloram or aminopyralid. Brand names of these herbicides include Grazon, Surmount, Milestone, and Forefront. Tobacco should not be planted in fields which have had these herbicides applied the previous year. See the label for other restrictions and information.

The proximity of the site 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. Compared to most other crops currently grown in Kentucky, the level of tillage used for tobacco is intense. Tillage in tobacco production is useful to help with weed control, 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 that make up the soil and the gaps or spaces, called pores, between the solids. In an uncompacted soil the pores make up about 50% of the soil volume and are well distributed between small pores 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 size pores being lost more readily than the small pores. Compaction creates a physical barrier that limits root growth and water drainage.

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 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 for transplanting compounds 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 4 to 8 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 14%.

Naturally occurring compacted zones are also found in some soils, more commonly in western Kentucky. These compacted areas are typically found deeper than tillage compaction and may range in depth from 12 to 30 inches or more. 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 2 to 3 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.

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 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. Deeper tillage does little to improve growth and results in excessive fuel use.

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.

Most tobacco production in Kentucky and Tennessee is on fields with at least some slope, and much of it on slopes of 6% or more. When these fields are tilled, they are extremely vulnerable to erosion losses for at least two to three months during the spring and early summer, when strong storms with heavy rainfall are common. Gullies to the depth of plowing are a common site in tobacco fields (Figure 1). Losses can be minimized by waiting until just before transplanting to do

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

Soil Type	Compaction	Conventional	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.

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 water and soil erosion. Alternatively, some growers may want to consider some form of conservation tillage.

Conservation Tillage

Despite the fact that Kentucky is known nationally as a leader in the development of conservation tillage for row crop production, the adoption of such methods for tobacco has be relatively slow here. Traditionally, tobacco growers have used intensive tillage to care for this high value crop, and many still believe that tobacco must be cultivated 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. Additionally, the mulch layer may help to keep the leaf cleaner by reducing mud splash on cut tobacco during late-season rain storms. Fewer heavy tillage trips means less time and less fuel use than with conventional tobacco production. No-till or strip-till fields may also have better trafficability in wetter times, allowing more timely application of needed fungicides, insecticides ,or sucker control materials during rainy periods. Conservation tillage includes no-till, in which the soil is not worked prior to transplanting; minimum-till, in which the soil is worked in such a way as to leave 30 to 50% of the residue on the surface; and strip-till, in which a 10- to 12- inch-wide band is tilled before transplanting. Each system has its advantages and disadvantages that the tobacco grower must consider.

No-till tobacco is really a form of strip-tillage in which the tillage and transplanting functions occur in one operation. Considerable modifications must be made to the transplanter for successful no-till planting. Figure 2 shows an example of the modifications required. At a minimum a no-till transplanter needs a wavy coulter in front to cut residue, a sub-surface 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 transplanters range from $300 to $600 per row, depending on how much fabrication the grower is able to do.

Figure 1. Severe gully erosion in conventionally prepared tobacco field.

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 Greenville on a deep, well drained loam soil (Table

Figure 2. Modifications to a transplanter for no-till transplanting of tobacco.

2). On a moderately well drained silt loam soil with a fragipan at Springfield, 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 burn-down 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 burn-down should be made with a product containing glyphosate. A follow-up treatment with a paraquat-containing product may be made within a few days of transplanting when residual weed control products are applied.

Sod crops should also be burned down 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. Some growers prefer to burn down a sod in the late fall and plant a cover crop to be burned down the following spring. 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 may require an application of burn-down in the fall and a follow-up in the spring. Even then we have seen some volunteer alfalfa in no-till tobacco fields.

Weed Control for Conservation Tillage

Because no-till tobacco is a relatively small use crop, there are very few products labeled specifically for its 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 Inteon) have been labeled specifically for use on no-till tobacco. 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 *Pest 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.

Once the in the ground, the crop can be treated just like conventional tobacco. Thus far there have been no additional problems with insect or disease pests when compared with conventional tobacco

Fertilization of Tobacco

Tobacco fields should be soil tested at least six to 12 months before planting to allow time for the application of lime and to plan for any nutrient deficiencies that may be identified. Limestone should be applied in the fall and thoroughly mixed with the soil one to two years ahead of the crop. If applied in the spring before transplanting, or if more than 4 T limestone/A are applied, plow one half down and disc in the other half for soils with water pH below 6.0.

Table 2. Burley Yields by Tillage System, Greeneville and Springfield, TN 2009.

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

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

Table 3. Nitrogen recommendations for burley and dark tobacco.

	Well-Drained Soil (lb N/A)	Moderately Well-Drained Soil (lb N/A)
Low N levels: following tobacco or row crops	225-250	250-275
Medium N levels: first-year tobacco following a grass or grass-legume sod	200-225	225-250
High N levels: first-year tobacco following legume sod or legume cover crop	150-175	175-200

Nitrogen fertilization rates (see Table 3 for Kentucky recommendations) depend primarily on the field cropping history and soil drainage class. Rotation to other crops is strongly recommended after two or more years of burley tobacco production in the same field. More frequent rotation may be necessary when growing dark tobacco or burley tobacco varieties with low levels of disease resistance.

All commonly available N sources can be used satisfactorily on tobacco, 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. If soil pH is moderately to strongly acid (pH 6.0 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, so applying lime is a much more economical strategy for soil 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 preplant broadcast on well-drained soils. However, Kentucky often has large rainfall amounts during April and May, so applying the broadcast nitrogen as near to transplanting as possible will significantly lessen the chances for losses of applied nitrogen. Apply the nitrogen after plowing and disc into the surface soil. Because losses of fertilizer nitrogen can occur on sandy soils or soils with poor drainage, it is helpful to split nitrogen applications on these soils, applying one-third of the nitrogen before transplanting and the remaining nitrogen two or three weeks after transplanting. The use of poorly drained or somewhat poorly drained soils for tobacco production is not recommended.

Further efficiencies in nitrogen use, decreased manganese toxicity, and increased early growth can be obtained by banding most of the nitrogen (sidedressing) after transplanting. These bands should be applied 10 to 12 inches to the side of the row in either one or two bands and at depths of 4 to 5 inches. All the nitrogen should be banded at 0 to 10 days after transplanting or in two applications, two-thirds at 0 to 10 days and one-third at four or five weeks after transplanting. If one-third or more of the total nitrogen is applied after transplanting the rate from Table 3 should be reduced by 15 to 25 lb N/A.

Tennessee recommendations for nitrogen are more generalized, with a rate of 150 to 200 lb recommended for both dark and burley tobacco. This rate range is intended for well-drained soils with little leaching or denitrification potential. If following a legume sod or a lush legume cover crop, the rate is reduced by 50 lb.

Phosphorus (P) and potassium (K) fertilizer additions should be determined by soil testing. Based on soil test results, apply the recommended amounts indicated in Table 4. Recommendations in Table 4 apply only to soil test results obtained using the Melich 3 extraction procedure as used by the University of Kentucky Regulatory Services Soil Testing Laboratory. If you have soil tests performed at another lab, please refer to their charts and tables for appropriate recommendations. Results from soil tests run at the University of Kentucky show that approximately 70% of the tobacco fields in Kentucky test very high in P and need no additional P to grow a crop. Almost 30% of tobacco fields do not need additional K for the current crop year. Growers are encouraged to take full advantage of soil nutrients to help reduce their fertilizer expense.

Table 4. Phosphate and potash recommendations (lb/A), tobacco.

Burley and Dark		Burley		Dark	
Test Result: P	**P_2O_5 Needed**	**Test Result: K**	**K_2O Needed**	**Test Result: K**	**K_2O Needed**
Very high		*Very high*		*Very high*	
> 80	0	> 450	0	> 450	0
High		*High*		*High*	
73-80	30	424-450	30	398-450	30
71-72	40	417-423	40	383-397	40
68-70	50	409-416	50	368-382	50
66-67	60	402-408	60	353-367	60
64-65	70	394-401	70	338-352	70
62-63	80	387-393	80	323-337	80
58-61	90	379-386	90	308-322	90
		372-378	100	296-307	100
		364-371	110		
		357-363	120		
		349-356	130		
		342-348	140		
		334-341	150		
		327-333	160		
		319-326	170		
		312-318	180		
		304-311	190		
Medium		*Medium*		*Medium*	
54-57	100	296-303	200	286-295	110
50-53	110	286-295	210	276-285	120
46-49	120	276-285	220	266-275	130
41-45	130	266-275	230	256-265	140
37-40	140	256-265	240	246-255	150
33-36	150	246-255	250	236-245	160
29-32	160	236-245	260	226-235	170
		226-235	270	216-225	180
		216-225	280	206-215	190
		206-215	290		
Low		*Low*		*Low*	
25-28	170	195-205	300	195-205	200
22-24	180	184-194	310	184-194	210
18-21	190	173-183	320	173-183	220
14-17	200	162-172	330	162-172	230
11-13	210	151-161	340	151-161	240
7-10	220	140-150	350	140-150	250
		129-139	360	129-139	260
		118-128	370	118-128	270
		107-117	380	107-117	280
		96-106	390	96-106	290
Very Low		*Very Low*		*Very Low*	
< 7	230	< 96	400	< 96	300

The University of Tennessee Soil Test Laboratory uses the Melich 1 extractant and therefore a different set of recommendations for P and K, but in general the recommendations from UK and UT on the same soil are similar. Growers are encouraged to follow the recommendations of their individual state soil testing laboratory.

Spring applications of chloride-containing fertilizers such as muriate of potash at rates greater than 50 lb 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. Consequently, sulfate of potash should be the major potassium fertilizer used on tobacco fields after January 1 of the current crop year.

Animal manures are also known to contain chloride in concentrations high enough to reduce the quality of cured tobacco. Chloride in excess of 1% in cured tobacco leaf is considered unacceptable by the tobacco industry. Cattle and swine manure applications should be limited to no more than 10 tons per acre. Poultry manures should not be applied in the year tobacco is grown. Fall applications of poultry littler should not exceed 4 tons per acre on ground where tobacco will be planted the following spring. Fall manure applications should be made only when a living cover crop will be present to take up and recycle some of the available N. Excessive rates of manure or manure used in conjunction with chloride-containing fertilizers may result in unacceptable chloride levels in the cured leaf. Where possible, it is probably best to utilize available poultry manure for other crops in the rotation and gain the benefit of their residual P and K in the tobacco crop without risking excessive chloride in the cured leaf.

Another recent concern about manure use relates to the picloram- and aminopyralid-containing pasture herbicides mentioned earlier. 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 field treated with these herbicides.

Molybdenum (Mo) is recommended for use on burley tobacco either as a broadcast soil application or as a mixture in transplant setter water 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 in dry solid form or as 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. Apply before transplanting and disc into the soil. 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 lb of sodium molybdate (12.8 oz of molybdenum) per acre be used during a five-year period.

For transplant applications, use 0.25 to 0.50 lb 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% liquid source of molybdenum is used with tw0 barrels of setter water per acre, add 1 to 2 qt of the liquid product per barrel before filling the barrel with water.

The incidence of boron deficiency has been increasing in tobacco fields in recent years. A common symptom noticed by growers is leaf breakage. The midrib of the leaf is typically broken off, leaving about 2 inches of the midrib attached 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, an application of ½ lb of boron in 20 to 30 gal of water per acre may be warranted. As with all micronutrients, care must be taken to avoid overapplication that could lead to toxicity.

The need for iron, copper, and zinc in tobacco has not been shown for Kentucky soils. Improper rates could result in toxicity to the plant, so they are not generally recommended on tobacco.

Topping, Sucker Control, and Harvest Management for Burley and Dark Tobacco

Andy Bailey, Bob Pearce, and Paul Denton

Introduction

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

Topping

Topping is the removal of the flower bud along with some of the uppermost leaves in order to stimulate growth and development of upper leaves. Plants left untopped or topped late will divert 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 at 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 that may have to be removed. Unless knives or clippers are used, tobacco topped late usually results in bruised, ragged stalks that are more susceptible to diseases such as bacterial soft rot (hollow stalk).

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

Topping Burley Tobacco

Bloom Stage

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

Late-maturing varieties such as KT 206, KT 209, and KT 210 and may respond well to bud topping, while bud topping may reduce yields in other varieties. Specific varieties may need early topping to produce their best quality. Older varieties like TN 86 and NCBH129 tend to produce flashy, poorer quality tobacco. Other varieties may also have a tendency to produce a lighter, thinner bodied tobacco. Such varieties are more likely to develop better quality if topped early. 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. Many marketing contracts now encourage that there be 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 old barns that have less space between tiers. Extra leaves beyond 24 leaves do not necessarily mean extra yield. Root development dictates leaf production potential; therefore, extra leaves usually mean smaller leaves. Topping to the right number of leaves may require a slightly later topping time in order to produce tips. However, delays beyond 75% bloom will be counterproductive. A balance must be found between extra labor required to produce those leaves and the yield per acre and premium for tips at the market.

Topping Dark Tobacco

Bloom Stage

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

Leaf Number

Dark tobacco should be topped to 16 to 18 harvestable leaves. Topping to this height maximizes yield potential and allows a distinct characterization of lug, 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 lb/A 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 controlled effectively. Some varieties such as KY 14xL8 and Narrowleaf Madole are known to have more rapid sucker growth than other varieties and may require more aggressive sucker control strategies. Three types of chemicals are available for controlling sucker growth on tobacco:

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

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

Contacts

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

Local Systemics

Butralin, Prime+, Flupro, and Drexalin Plus are the local systemic products currently available. Butralin and flumetralin (Prime+, Flupro, and Drexalin Plus) are the active ingredients in these products. All belong to a family of chemicals called dinitroanalines and have similar use recommendations. When properly mixed with water, Butralin makes an orange emulsion, while flumetralin products make a yellow emulsion. Local systemics should be applied in a manner similar to application of contacts, so that the chemical runs down the stalk and contacts every leaf axil. Suckers longer than 1 inch should be removed prior to application. Local systemics do not burn suckers as do contacts but rather stop sucker growth, with suckers remaining as a pale greenish-yellow tissue for several weeks after application. Applications of local systemics can be made with powered spray equipment or with backpack or hand sprayers. Local systemics generally require three hours without rain after application to be effective. The activity of local systemics in stopping cell division can also cause distortion of small, upper leaves that come into contact with the chemical. For this reason, applications of local systemics should be delayed until upper leaves are at least 8 inches long. If upper leaves are less than 8 inches long and manual stalk rundown applications are made, direct the spray below these smaller leaves. If a local systemic is being applied alone, a rate of 1 gal/A should be used (1 gal/50 gal total spray solution or 8 fl oz (½ pt) per 3-gal spray solution). Local systemics, particularly those that contain flumetralin, are much more persistent in the soil than other sucker control chemicals, and severe damage can occur to subsequent crops, particularly grasses. For this reason, care should be taken not to use excessive amounts of these products. If manual stalk rundown applications are made with drop lines, backpack, or hand sprayers, care should be taken to prevent pooling of the solution at the base of the stalk. Use only enough solution to wet the stalk and suckers on each plant; 0.5 to 0.75 fl oz of spray solution per plant is sufficient. Reduced rates of local systemics can be used if tank-mixed with contacts or systemic products. Use 3 qt local systemic per acre when tank-mixing with contacts and 2 qt/A when tank mixing with systemic sucker control products.

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 power 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 6 inches before MH is applied. MH products are available in three formulations: a regular liquid concentrate containing 1.5 lb MH/gal (Royal MH-30, Super Sucker-Stuff), a higher concentrate liquid containing 2.25 lb MH/gal (Royal MH-30 Xtra, Sucker-Stuff), and a dry formulation (Royal MH-30 SG) that contains 60% MH by weight. Another dry formulation of MH, Sucker-Stuff 80 EG, is also marketed and similar products may be available. Because the concentration of MH can vary between these dry formulations, application rates may be different between products on the market. Regardless of the MH formulation, the recommended rate should be equivalent to 2.25 to 3 lb of active ingredient (MH) per acre. Always refer to product labels or contact the manufacturer for rate information. The regular liquid concentrate (1.5 lb active ingredient/gal) is the most widely used form of MH. Regular concentrate MH used alone can be applied at a rate of 1.5 to 2 gal/A. Use rate for high concentrate MH is 1 gal/A, which is equivalent to 1.5 gal/A of the regular concentrate. Use rate for Royal MH-30 SG is 4 to 5 lb/A. All MH formulations should be applied at a spray volume of 50 gal/A. MH is most effective if no rain occurs within 12 hours after application. If significant rainfall occurs within three hours after application, reapply at the full application rate. If rainfall occurs between three and six hours after application, reapply at one half the full application rate on the following day. If no rainfall occurs within six hours of application, MH does not need to be re-applied. 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 effective sucker control programs include an MH application. However, there have been concerns in the industry about the harmful effects of excessive MH residue on cured leaf, and major efforts have been made to reduce or even eliminate MH residues on burley tobacco. An effective way to reduce MH residues without compromising sucker control is to use the lower 1.5 gal/A rate of regular concentrate MH in combination with 2 qt/A of a local systemic applied with coarse nozzles. This combination spray controls suckers as well as the full 2 gal/A MH rate and reduces MH residues. Research at the University of Tennessee and the University of Kentucky shows that MH residues will rarely exceed currently accepted standards if the 1.5 gal/A rate is used. Lower rates of MH will reduce residues further but have given inconsistent sucker control.

FST-7 and Leven-38

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 application rate is 3 gal/A. They should be applied as a coarse spray with powered spray equipment at a spray volume of 50 gal/A to cover the top third to top half of the plant, allowing the solution to run down the stalk to the bottom of each plant. Since the active ingredients in both products tend to separate in the container, make sure the container is well mixed and shaken before its contents are added to the spray tank. Constant agitation in the spray tank should be used with FST-7, Leven-38, and all other sucker control products.

Application Methods for Sucker Control Chemicals

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

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

Use of powered spray equipment is the most labor-efficient method of applying sucker control products, as this method typically requires only one person and many acres can be covered in a day. Any type of sucker control product can be applied through power 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 fatty alcohols and local systemics that must cover every leaf axil to be effective. Thorough coverage of all leaf axils requires a minimum of 50 gal/A spray volume, and coverage may improve on many crops as spray volume is increased to 60 or 70 gal/A. Pressure should be 20 to 30 psi.

Nozzle Arrangement

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

Nozzle Selection

Nozzles that allow high output and produce coarse spray droplets are preferred for all applications. Coarse droplets tend to penetrate through leaves 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 2½- to 3½-mph range. For flatter ground where speed can be increased to 4 to 5 mph, use TG-5's or the equivalent.

Drop Line Applications

Drop line applications involve a high-clearance sprayer with hoses for each row attached to the boom. A spray trigger is attached to the end of each hose for operation by a worker walking behind the sprayer. Drop lines are used with plant-to-plant stalk rundown applications of contacts and local systemics. This method provides more direct sucker contact and generally provides better control than over-the-top applications but is labor intensive and requires a slower pace to accommodate workers. The speed of the sprayer can only be as fast as the slowest worker. Practice may be required for workers to become accustomed to the appropriate rate of application, particularly on crooked tobacco that may require directing the application to several areas on the stalk. On tall tobacco, missed suckers can be common in the top of the plant, but misses are less common than with other methods. Apply 0.5 to 0.75 fl oz of spray solution to each plant, with care taken to avoid applying excessive amounts that will pool on the ground at the bottom of the plant. Product rates per acre are the same as with any application method, although volume of spray solution required for drop line applications will be 20 to 40 gal/A, 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 6 to 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 2 (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 fl oz of spray solution to the top of each plant to run down the stalk. The backpack or hand sprayer consists of a small, 2 to 3 gal spray tank and a wand attachment that can be fitted with a coarse spray nozzle. This method may have an advantage over the drop line method in that each worker is independent of others and speed is not dictated by the slowest worker. Small acreage growers using plant-to-plant stalk rundown applications prefer this method. Refer to Appendix 2 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 fl oz of solution down the stalk of each plant. One gallon of spray solution should treat 170 to 256 plants. Although the jug method is the simplest of all methods, it is more difficult to apply consistent amounts to each plant. Some small acreage growers may still prefer the jug method. Refer to Appendix 2 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 1.5 gal/A MH (regular 1.5 lb/gal formulation) with 2 qt/A of a local systemic as an over-the-top application with power spray equipment. Top tobacco at 10 to 25% bloom, and remove all suckers longer than 1 inch. Spray applications can be made within one day before or after topping. If upper leaves will be less than 8 inches long at topping, apply a contact at topping and then follow with 1.5 gal/A MH (1.5 lb/gal formulation) plus 2 qt/A local systemic seven days later. Recent research has demonstrated that sucker control from contact applications can be more effective when applications begin just before topping.

Uneven Crops

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

1. If the crop is not drastically uneven, the best approach may be to top all plants, leaving a small leaf (approximately 6-8 inches) at the top of plants that have not bloomed. Treat the entire crop with 1.5 gal/A of MH (regular 1.5 lb/gal formulation) and 2 qt/A of a local systemic. Use coarse nozzles only. To reduce labor, some producers may elect to top only those plants with a bud or bloom and spray the entire crop with the combination above, allowing the spray material to chemically top those plants in the prebud stage.
2. 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 power spray equipment. Apply 1.5 gal/A MH (1.5 lb/gal formulation) plus 2 qt/A local systemic after the second and final topping.
3. 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 power spray equipment over the top, or apply a local systemic as a 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 other local systemics. If a local systemic is used, do not retreat plants that have already been treated at a previous topping. At the final topping, apply 1.5 gal/A MH (1.5 lb/gal formulation) over the top using power spray equipment.

Strategies for MH-free Burley Tobacco

Certain buying companies have offered price incentives for burley tobacco that has not received MH. Although burley tobacco can be grown without MH, labor requirements may be greater and sucker control may be reduced in programs that do not include MH. If sucker control is adequate, some improvement in yield and cured leaf color can be seen in MH-free crops. Crops that have not received MH may also stay in the field longer before harvest. Alternative management and application techniques may need to be employed with MH-free tobacco. The most consistent method for producing MH-free tobacco is to use contacts and local systemics in plant-to-plant stalk rundown applications with drop lines or backpack/hand sprayers. As discussed previously, this method requires much more labor and time, and multiple applications are usually needed. Good yields and sucker control can be achieved in MH-free tobacco using over-the-top applications from power 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 at topping, followed by a single local systemic application at 1 gal/A either alone or preferably tank-mixed with a contact (Table 1).

Table 1. Performance of several sucker control treatments in a 2009 burley tobacco sucker control trial, UKREC, Princeton, KY*.

	Applications:		At Harvest:		Total Yield (lb/A)
Treatment	Rate/50 gal	Number	% Sucker Control	No. of Axillary Suckers/30 Plants	
OST	2 gal	1	45	37	2155
OST	2 gal	3	76	12	2282
OST fb OST+Butralin	2 gal OST 1 gal Butralin	2	82	6	2520
OST fb MH + Prime+	2 gal OST 1.5 gal MH 0.5 gal Prime+	2	95	4	2605
OST fb MH	2 gal OST 2 gal MH	2	92	4	2465

* *Abbreviations: OST = Off-Shoot-T; fb = followed by. First Off-Shoot-T application to all treatments was made one day prior to topping. MH formulation used was Royal MH-30 (1.5 lb/gal formulation). All applications made with a 3-nozzle per row system delivering 50 gal/A. Burley variety used was TN 90LC.*

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 than burley to blowing over and becoming crooked. 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/handsprayers are much more common in dark tobacco. Recent 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% solution (2 gal/50 gal total solution) to the entire field as a plant-to-plant stalk rundown application. Top the rest of the crop within seven days if possible and apply either a tank-mix of a contact at 4 to 5% solution with a local systemic at 3 qt/50 gal or a local systemic alone at 1 gal/50 gal. The contact/local systemic tank-mix allows a slightly lower rate of the local systemic to be used and may also increase sucker control compared to applying the local systemic alone at the full use rate. Although any local systemic can be used, Prime+ gives slightly longer sucker control than other local systemics. If more than two toppings are required, apply a contact every seven days and follow with a local systemic or contact/local systemic tank-mix application at the final topping. If a local systemic is applied to plants that have not been topped or have upper leaves less than 6 inches long, direct the application below these smaller leaves. Another strategy is to apply a local systemic or contact/local systemic tank-mix at each topping. With this strategy, treat only plants that have just been topped and do not retreat plants at later toppings (Table 2).

Over-the-top Applications with Power Spray Equipment

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

Use of MH in Dark Tobacco

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

Table 2. Performance of several sucker control treatments in a 2009 dark tobacco sucker control trial, UKREC, Princeton, KY*.

	Applications:			At Harvest:		Total Yield (lb/A)
Treatment	Rate/55 gal	Number	Method	% Sucker Control	Sucker Wt./30 Plants (lb)	
2 OST	2.5 gal	2	drop line	53	12.6	2667
2 OST fb But	2.5 gal OST 1 gal But	3	drop line	89	9.3	2897
2 OST fb OST+But	2.5 gal OST 1 gal But	3	drop line	93	5.2	2973
2 OST fb OST+But	2.5 gal OST 1 gal But	3	spray	82	4.5	2820
2 OST fb MH+But	2.5 gal OST 1.25 gal MH 0.5 gal But	3	spray	93	3.8	2856

* *Abbreviations: OST = Off-Shoot-T; But = Butralin; fb = followed by. Initial Off-Shoot-T applications were made with drop line. Spray applications were made with 3-nozzle per row system delivering 55 gal/A. MH formulation used was Royal MH-30 (1.5 lb/gal formulation). Dark variety used was PD 7318LC.*

Harvest Management for Burley and Dark Tobacco

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.

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 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. Harvesting at six weeks after topping usually does not increase yield and may decrease leaf quality.

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

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

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

Burley tobacco can usually be hung at higher densities in open-sided, low-profile outdoor curing structures without increased risks of houseburn or barn rot. Burley tobacco hung on these structures should have a stick spacing of 4 inches. 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 usually occurs between five and seven weeks after topping. Exceptions are TN D950 and PD 7305LC, two early-maturing varieties that may be ready for harvest between four and five weeks after topping. TR Madole, VA 309, and KT D6LC (which is a hybrid of KT D4LC and TN D950) may also show rapid maturity and leaf breakdown as early as five weeks after topping when transplanted in May.

Dark tobacco that is ripe when harvested will have brittle leaves that will break and bruise easily. For this reason, dark tobacco should not be cut and put on sticks in the same operation, as is typically done in burley. Due to its more prostrate leaf structure, dark tobacco should be carefully cut, with caution being taken not to break lower leaves, and allowed to wilt in place or "fall" before being put on sticks. Depending on temperature and sunlight intensity, this wilting period may take anywhere from 30 minutes to several hours. Tobacco cut late in the day can be left to wilt overnight if there is no chance of rain that will leave the tobacco excessively wet or muddy. Once tobacco is 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. Burlap sheets may also be 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 8 to 9 inches. In older barns with narrow tier spacing, place sticks at least 12 inches apart. Narrow tier spacing in older barns may only accommodate tobacco topped to 12 or 14 leaves, whereas wider tier spacing in newer barns will accommodate tobacco topped to the current market standard of 16 to 18 leaves. Use alternating placement on tier rails so that tobacco does not overlap tobacco on lower tiers, or hang tobacco only on every other tier if barns 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 and Andy Bailey

Conventional Barn Renovation and Remodeling

In the post-buyout era of tobacco production, curing facilities are becoming a limiting factor for producers wanting to expand their production. With the high cost of new barns, the renovation and remodeling of existing barns could 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. Here are a few possibilities.

Good burley curing requires lots of natural air. Be sure ventilator doors or equivalent openings equal ¼ to ⅓ the barn side wall area and are positioned to permit natural ventilation 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 optional 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 having poor ventilation. See available publications 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 ½ ft apart vertically, better curing results when tobacco is housed on every other tier rail. This 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, provided the tier rails should not be overloaded, which can cause the tiers to break.

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.

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

There are several options for new tobacco barn construction as well as field curing structures. An important decision is 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 tobacco barn (burley or dark) is the largest single investment required in the normal tobacco 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 build only barns of that type.

Considerations

When planning new 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 smaller crew size and less total labor
- Alternative designs that use portable frames or cable-hoist mechanical handling and housing that can save over half the housing labor
- Structures that permit other possible farm uses of the facility during the non-curing season, such as machinery and supply storage
- Future modifications for different tobacco housing and curing methods or other farm enterprises, as these methods could change significantly in the future

Designs and Plans

Over three dozen designs and plans and various publications related to curing facilities are currently available on the UK Department of Biosystems and Agricultural Engineering (BAE) web site: www.bae.uky.edu/ext/tobacco. General groupings include the following:

- Three-tier and four-tier air-cure, 32-, 40- or 48-ft wide, post-pier or pole-type construction, wood, or metal siding
- Two- or three-tier forced-air, 32- or 40-ft 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 structure 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 ft 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 ft 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 (see separate section). Also, not operating fans during drier weather can reduce air exchange and maintain better humidity conditions.

Lumber of sound quality and proper strength capabilities 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. Ventilator openings should have doors or panels that open, generally vertical in orientation, that are equivalent in area to at least one-fourth to one-third of the side wall area. Some barns are being built with metal siding that do not have adequate side wall ventilation. Inadequate ventilation will result in houseburn during humid weather or with tightly spaced tobacco.

Lower cost plastic-covered field structures can use untreated wood for reduced life or preservative-treated wood for longer life. Various wooden and wire strung designs exist for stick harvested or notched plant hanging and curing. Careless and haphazard construction, including failure to adequately anchor high tensile wire, can result in failure of these field structures when fully loaded with harvested tobacco, 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 very strong winds. Locate field structures beside barns or downwind from fencerows or tree lines to help protect them from the wind.

Investment Costs and Labor Efficiency

Curing facility initial costs can range from $700-$1,200/A of capacity for simple field curing structures with plastic covers to $6,000 and more per-acre capacity for conventional air or fire-cure barns. 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 up to 30-35 worker-hr/A.

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

Air Curing Burley Tobacco

One of the most important functions of any tobacco curing facility is to provide for management and an environment for proper curing of the tobacco. 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. Growers have experienced two extremes in the last two years with the wet curing season of 2009 and the dry curing season of 2010. Quality is influenced by moisture and temperature conditions inside the curing facility during the curing period. For several decades the best conditions for curing burley have been cited from Jeffrey (1940) as a daily temperature range from 60 to 90°F and a daily relative humidity average of 65 to 70%. The study was based on an airflow of 15 ft/minute (¼ mile per hour 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 72-75% range produce 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 normal tobacco 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 40-50% in the heat of the day, thus averaging around the 70-75%. The cooler October temperatures can often go below 60°F for an entire day and/or several consecutive evening periods, with humidity ranging from 25-30% in daytime to not over 70-80% in evening hours, resulting in daily averages of 45-55%. Extensive curing studies by Walton, et al. (1971, 1973) on the effect of several combinations of low and high temperatures and relative humidity on the quality of burley can be summarized as follows:

- Low temperatures result in green leaf, regardless of the relative humidity and airflow. The chemical conversions are too slow because of the low temperature. However, the drying rate does determine 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 greenish or mottled leaf.
- Low humidity and high temperature (75°F and above) causes "piebald" (yellowish) leaf.
- High humidity and moderate-to-high temperature for extended periods is "house-burning" 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, it is the relative humidity (if airflow is adequate) that determines the degree of damage incurred. Walton et al. (1973) showed that the greater the departure from the optimum relative humidity range, the greater the damage to the quality of the tobacco.

Control of the curing process is affected mainly by spacing of the tobacco in the curing facility and management of the drying rate. Spacing can vary from 5-6 inches between plants or sticks for one- and two-tier facilities to 7-10 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 the barn, 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 and that of the tobacco is to purchase a couple of commercial digital temperature and humidity instruments for $25-$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%, which is reasonable for the price.

One-tier field curing structures with plastic covers normally have plentiful air movement through the tobacco, thus curing as well as the natural weather provides. 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. Under warm conditions (mean daytime temperatures >80°F and mean nighttime temperatures >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 <65°F), dry conditions persist after housing. Heat sources that can be used include gas burners, coke stoves, or even small wood fires using dry sycamore wood. 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 that should be used in every situation. Dark air-cured growers should refer to contract specifications and recommendations and comply if there are any restrictions against the use of heat.

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, managing ventilators 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 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 completed and the entire leaf lamina is a solid yellow 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 several 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 for one-half to two-thirds of the way 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 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 final 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 both ends of each row or at several locations. 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).

Double-Crop Curing Dark-Fired Tobacco

Double crop curing refers to curing two crops of dark-fired tobacco in the same barn and curing 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 between May 1 and May 15. Second cures should be transplanted between June 5 and June 20. If this timeframe is followed, first cures will be ready for harvest in mid- to late August, and second cures can be harvested in late September to early October.

The most critical part of double-crop curing is the aggressive firing of the first cure. Whereas the first fires for single crop cures are not usually started until around seven days after housing, first cures for double cropping usually need to be fired sooner 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 the tobacco to 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 takedown first cures in a timely manner. This moisture can be added with overhead misting systems built into the top of the barn so water can be applied over the top of the tobacco or by applying steam up into the tobacco from the barn floor. Most dark-fired crops will need two applications of misting or steaming in order 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 improving 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 down toward the ground. Thus, air is moved through the central core of the tobacco where moisture problems generally first occur. To prevent damage by the fan, sticks of tobacco are omitted directly above the fan and plants are moved sufficiently away from the sides. Leave the side ventilators or other doors open to allow the ground-level moist air to migrate out of the barn and fresh drier air to come in around the eave, through the sidewall vents, and through the tobacco.

For beneficial curing results, fan capacity should be 12,000 to 18,000 cu ft/minute of 0.1 inch static pressure-rated airflow for every two bents of 32 to 40-ft wide barn. This means good quality fans of 42 or 48-inch diameter; ½, or ¾ 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 continuously (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. Time clocks can be installed to automatically power the fans on and off daily.

Don't operate the fans during cool, dry weather (below 50 to 60°F and below 60-65% relative humidity) when the tobacco still has green or yellow color in the leaves, as overdrying 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 electrical 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 electric 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 500-600 lb 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 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 the tobacco handling and personnel
- Heating equipment (with proper exhaust venting) for warmth in cold weather
- Electricity for the lights and power equipment needs

Blueprints are available from the BAE web site show typical construction of traditional stripping rooms. Over 20 possible layouts of larger stripping rooms for the big baler operation are also shown on the site. Benches should be 32-36 inches high and 48-60 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 ½-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. Special lights with a more balanced daylight spectrum and quality of light are options.

Leaflet 293, *Improving Light Conditions for Stripping Tobacco*, is a publication on the BAE web site describing 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.

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Stripping and Preparation of Tobacco for Market

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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 in conventional small bales or newer big bales.

Takedown and Bulking

Takedown and bulking are the processes of removing cured tobacco from the curing structure and consolidating onto a scaffold wagon in a pile or bulk for access by workers or transport to the stripping location. Tobacco should be bulked on a clean, dry surface such as wooden boards, pallets, a wagon bed, or similar material. A plastic sheet can be used as a protective barrier on which the tobacco can be bulked, but be aware that a layer of moisture can condense on plastic under certain temperature and moisture conditions. Periodically check the tobacco in contact with the 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 a surrounding environment of 70% or higher relative humidity for several hours (four to 12, depending on the temperature and dynamics of the relative humidity). Tobacco should not be removed from the curing location until all the stems (midribs) of the leaves have dried to a firm condition (not "fat" or "mushy"). Producers typically wait for natural weather conditions of good humidity and temperatures above 35 degrees 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 separate article in the publications section of the BAE web site: www.bae.uky.edu/ext/tobacco).

Tobacco in equilibrium with air below approximately 60-65% relative humidity will be so dry that leaves will likely shatter

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

Several different methods are used for bulking tobacco. Tobacco harvested and cured using wooden sticks can be bulked either with sticks still inserted or with sticks 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 also makes it easier to handle the tobacco at the stripping location. Removing the sticks when bulking can be done when the stalks are dry enough (general brown color) that the moisture will not cause "heating" and other problems when the bulked stalks are tightly packed for several days of warm weather (above 45-50°F daily average) before stripping. If the stalks are still green and moist when bulked, strip within two to three days or put wooden sticks between bunches of stalks to permit better ventilation and moisture diffusion for the extended bulking period.

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

In any bulking method, put your hand deep into the bulk daily to determine that the tobacco is still cool and not beginning to heat up. If warmth is detected, then prepare to strip the bulk promptly, open up the bulk, or move the tobacco around to air out.

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

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

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

Stripping Burley

Stripping is the process of removing and grouping leaves by stalk position and physical characteristics to meet marketing requirements. Traditionally it has been recommended that burley be stripped into four stalk positions: flyings (lowest stalk position), cutters, leaf, and tips (uppermost stalk position). Burley properly stripped into four stalk positions fits well into the USDA grading system, and some buying companies still want this type of grading. However, some buying companies require only three grades. Company specifications for grading tobacco can vary quite a bit, so growers should review their contracts and talk with company representatives regarding their specific requirements. A full-leafed mature burley plant can have 20-24 leaves. Over-mature harvest and/or loss of lower leaves during harvest may reduce the lower stalk position ("flyings" or "trash") group. Often weather, soil, and curing variations are such that only three distinct grades of leaf characteristics may exist on most plants. 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 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 stripped 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 (trash), lugs (cutters), 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 may have a mixture of leaf and tips in the third grade. Depending on the buying company, the first grade and third grade in this type of stripping may be acceptable, since the first grade is clearly all light-bodied lower stalk tobacco and the third grade is all heavier bodied upper stalk tobacco. But the mixed middle grade will be a problem for all buyers. This may reduce market grades from 1's or 2's to 3's, and the mixed middle grade may also be classed as cutter instead of leaf. This reduction in grade has happened quite a bit with the light-colored, thin-bodied crop recent 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.

Producers who strip their tobacco into four grades typically group it into the four stalk-position appropriate grades (flyings [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. In this case, it would be cheaper for the producer to put the crop in three grades.

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 10-12 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. The relay method uses workers along a bench 32-34 inches high or wagon bed, with a source (pile) of cured plants at one end. The first worker pulls the 'flyings' 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. Efficiency with traditional 80-pound bales is improved when the stripping line is arranged so that each person on the stripping line can place tobacco directly in a bale box. For handling into the now-predominate 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."

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 "Update on Burley Harvest and Stripping Mechanization" for further information about stalk choppers).

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. This method makes distribution of unstripped plants and collection of bare stalks more cumbersome as well as requiring efficient handling of the various grades of stripped leaves.

With the predominance of the use of big baling and the non-oriented leaf packaging that it allows, (see later section on baling), many growers have found that different 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 now used to accommodate single or multiple big balers. 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 30-40%. However, these studies were done with small bales, so that the stripped tobacco had to be oriented in small batches in bale boxes. With large bales, producers seem to find the various stripping aids more advantageous.

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 to labor efficiency. Keys to increased productivity with stripping aids and other systems are to make sure that each worker performs efficiently as part of the team, tasks are reasonably balanced or staged in terms of time required per worker-task, and the flow of tobacco and stalks in and out is smooth and efficient, with minimum distance required for human handling.

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 leaves from the bottom of the stalk that show excessive ground injury, and the green grade is leaves from anywhere on the plant that show an excessive green cast appearance or that have dark green areas resulting from sunburn or other weather-related damage in the field. 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% for dark fire-cured and 22% for dark air-cured. Refer to marketing contracts for specific stripping, grading, and marketing specifications.

Marketing Packages for Dark Tobacco

Baskets

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 basket-type marketing packages. "Baskets" are generally wooden lids from hogshead storage containers, generally 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 12 inches x 18 inches x 36 - 44 inches, 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 lb and should not exceed 900 lb. Basket-type marketing packages have been the most commonly used marketing package for dark tobacco.

Boxes

Some dark tobacco contracts allow delivery in C-48 cardboard boxes supplied by the buying company. Dimensions of C-48 boxes are approximately 40 x 28 x 29 inches tall. 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 oriented within the box, it may 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 lb. 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 lb but not exceeding 900 lb.

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 35% to no more than 50% 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 the basket for delivery.

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 big tobacco bales. Studies done at the University of Kentucky and the University of Tennessee have found improvements in labor efficiency ranging from 15 to 25% with the use of big bale packaging, and many growers feel that they have achieved similar savings. Most big balers use hydraulic cylinder compression to form the bales in the nominal size 42 x 42 x 40-inch chambers Some big baler designs use air cylinders, but it takes a very large air cylinder to compress the tobacco to densities even approaching that of tobacco compressed by hydraulic cylinders and very large air compressors to supply such cylinders. Increasing density requirements will make it more difficult to use air cylinders.

Hydraulically operated big balers can be powered by a 230-volt electric motor or remote tractor hydraulic connections. The tractor-powered baler costs less and permits movement to various barns and stripping room locations where 230-volt power may not be available. The big balers have optional load cells and 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 bales in the 500-600 lb range, but weight specifications have been increasing since the big balers were introduced in 2005. Depending on the buyer and tobacco grade, some tobacco now is packaged in bales ranging in weight from 700-750 lb. Moisture content specifications have also been decreasing during that same period. The combination of higher tobacco density in the bale and lower moisture content limits 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, thus they cannot be expected to dry out or cool down as rapidly as small bales with similar high-moisture content. This difficulty is exacerbated by the increased weight and reduced moisture-content specifications.

Growers have experimented with various ways to try to dry down big bales with moisture content too high to be acceptable at receiving stations, as it takes a lot of work to open and flake apart big bales that have been rejected. Trials performed at the University of Kentucky showed that it was possible to get enough air movement through 600-lb bales by various means to reduce the moisture content 1-2% over a period of several hours, depending on the ambient conditions. Such drying rates may be far too slow to benefit large stripping operations, however, and even those drying rates may be unobtainable with the increased density of 700+ lb bales.

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 iare 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.

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Update on Burley Harvest and Stripping Mechanization

John Wilhoit, Larry Wells, and Paul Denton

Mechanization activities related to burley tobacco production have slowed in the past few years, both in terms of new innovations coming onto the scene and adoption of recent innovations by producers. In fact, grower interest in some innovations that previously appeared poised to significantly change harvesting and stripping operations now seems to have waned considerably.

Harvesters

The automated burley harvesters manufactured by GCH were used to harvest large amounts of tobacco on farms in both Illinois and Kentucky from 2006-2009. However, of the three units that were manufactured only one is still being used for regular production, and none was ever purchased from the manufacturer. The machines can drastically reduce the labor requirements for harvesting tobacco, but the whole system of harvester, carrier, and portable racks is very expensive. Because so much of the cost of the system is in the racks, upwards of $15,000/A, the costs cannot be reduced much by spreading them out over larger acreages.

Three-point hitch-mounted, plant-notching harvesters manufactured by MarCo and Kirpy generated considerable interest from growers following their demonstrations at field days in 2005-2007, and many of them were purchased and used by growers in Kentucky, North Carolina, and Indiana. In the past two 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 when 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 can stick-cut tobacco left in the field. Also, large labor crews may not be able to work largely unsupervised as they can with traditional stick-harvesting operations. The difficulties that the machines have with handling windblown, crooked tobacco stalks, also a problem with other harvesting machines, is another severe limitation, as are concerns about excessive losses due to leaf breakage.

A self-propelled stalk-spearing machine developed by University of Kentucky agricultural engineers in the 1990s has actually received some renewed interest in recent years. A grower in Anderson County, KY has refurbished two of the original units of this "Burley Spiker" and used them to harvest his 6-acre crop each year from 2007 to 2009. He was able to use the machines in 2010 for only part of the crop because of crooked stalks. A company in North Carolina, Evans-MacTavish-Agricraft, Inc., manufactured three new units of this machine in 2009. One of them is currently in use in North Carolina. The "Spiker" is a stick-harvesting machine that uses two workers, one to grasp plants cut by a saw blade and place them on a conveyor and another to place filled sticks on the ground. Two workers can harvest approximately 1 acre per day with this machine, so it does not reduce harvest labor requirements substantially, but it does reduce the drudgery of traditional manual cutting. The machine fits in easily with existing stick-harvesting, hanging, and curing systems.

Stripping and Market Preparation

A mechanical leaf-removing stripping machine developed by Carolina Tobacco Services[1] that was introduced at tobacco field days and trade shows in 2006-2007 initially received considerable interest from the tobacco industry. The CTS stripping machine uses 'sticker'-type chains to hold the tip end of plants hanging vertically downward, conveying them past angled wiper bars that strip off leaves as the plants move through a length of 14-16 ft. Different leaf grades fall into boxes below the plants along that length. Tips have to be stripped by hand before loading the plants in the machine. Design changes were made to address some initial problems with the shaft for the wiper bars and with the wipers themselves after the first couple of years that these machines were used operationally by growers; however, the cost and effort required for replacing the wipers remain a major limitation. 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 lb/worker-hr, or about 35 worker-hr/A for a 2,500 lb/A crop (compared to 50-75 worker-hr/A for conventional stripping). Very few (one or two) of these machines are known to have been purchased by private growers. The the high cost of the machines ($30,000 to $40,000) is hard to justify despite the potential savings in stripping labor.

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 and allowed them to use both hands to remove the leaves more rapidly. 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. Some of the initial high level of 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

[1] *More details on the equipment described and manufacturer contact information can be obtained from the web site www.bae.uky.edu/ext/tobacco.*

are doing include pulling wagonloads of tobacco directly into large stripping rooms, taking portable balers to the barns and stripping off 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 as fitting 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.

Interest continues in using stalk choppers with the larger-scale stripping operations that are becoming more common, although the uncertainties in the tobacco markets have probably somewhat curtailed interest. 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 UK Department of Biosystems and Agricultural Engineering have also been used on farms in Kentucky in the last three 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.

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 web site: www.bae.uky.edu/ext/tobacco. Check the BAE web site for periodic updates.

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 leaf 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 tobacco-specific nitrosamines 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 green tobacco. They are mainly formed during curing, specifically during the late yellowing to early browning stage. This is usually in the two-week period three weeks to five weeks after harvest.

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 (NO_x) formed during the fire-curing process. Both the alkaloid and the nitrosating agent are necessary for the formation of TSNAs. Any practices or conditions that increase the accumulation of either of these groups of compounds would be expected to increase TSNAs.

Factors Affecting TSNA Accumulation

Three main factors affect the amount of TSNA accumulation:

- **The amount of specific alkaloid precursor.** In the case of burley and dark tobaccos, this is nornicotine, and it is mainly determined by the amount of conversion of nicotine to nornicotine in the seedlot used. Screened or "LC" seed has been selected for low conversion, and we have shown that this results in significantly lower TSNAs.
- **The amount of nitrosating agent.** Nitrite is 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 body 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. Nitrogen oxides (NO_x) are a result of combustion of wood during fire-curing.
- **The amount of total alkaloids/nicotine.** The relative amount of nornicotine depends on conversion, and the absolute amount depends on the amount of total alkaloids. The higher the total alkaloids, 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, one a non-commercial high converter and one 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

Figure 1. NNN formation.

Figure 2. NNN (ppm) for high converter (HC) and low converter (LC) burley varieties over two years.

is under genetic control and most modern varieties have been selected for minimum conversion. In Kentucky, 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 has now been screened, and there is no unscreened seed on 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.

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 was 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 because the leaf remains alive and active longer during curing, allowing more conversion of nicotine to nornicotine. Thus, with the increased nitrite and nornicotine available, more 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 72-75% relative humidity, i.e., a long, slow cure) are also favorable for TSNA accumulation. Under these conditions, TSNAs will be unacceptable if there is any appreciable amount of conversion. TSNAs will usually be acceptable if conversion is low and the curing is correctly managed. However, even low converters can produce significant amounts of TSNAs in conducive conditions if the curing is not properly managed (see Figure 2, low converter in 2005). The challenge is therefore to produce quality tobacco with acceptable TSNAs.

Tests have shown that TSNAs in outdoor burley curing structures are very similar to those in a conventional barn (Figure 3) if they are in the same vicinity.

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

Figure 3. NNN (ppm) in a conventional barn (left) and outdoor curing structure (right).

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 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 in air-curing. However, ventilation can be manipulated only to a limited extent if quality is to be maintained. Managing curing for low TSNAs will generally 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.
- 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 in 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 by seven days after housing. Avoid firing the tobacco any more and any longer than necessary to produce cured leaf with acceptable quality and marketability. There is no reason for the maximum barn temperature to exceed 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 does 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 by seven days after housing.
- Do not allow barn temperatures in fire-cured barns to exceed 130°F.
- Ideally, do not keep temperatures at 130°F for longer than four to five days.
- Space plants evenly on sticks, and place sticks evenly on the rails.
- Avoid packing sticks too closely.
- Use minimal artificial casing.
- Consider using overhead misting systems instead of steam when artificial casing is needed in fire-cured tobacco.

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

Free water on or in the leaves at any stage after harvest has the potential to increase TSNAs. Studies have shown that wetting the leaves shortly before or after harvest can increase TSNAs, as can the use of water sprays to bring tobacco into case and storing high-moisture tobacco. TSNAs generally increase 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:

- As far as possible, do not cut wet plants, and do not house tobacco with free moisture on the leaves.
- Allow air-cured tobacco to come into case naturally if possible, without the use of water sprays.
- 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 leaf as low as possible, ensuring that it is below the level specified in the contract.

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 also undesirable because ad-

ditional TSNAs may be produced during storage and cigarette smoking.

Many studies show large differences in TSNAs between very high and very low nitrogen rates. However, within the normal production range, the effect is 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 datasets 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-unit 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 therefore appear to cause a significant increase in TSNAs as long as it is applied at the recommended time. Applying sidedress nitrogen later than six weeks after transplanting could increase TSNA levels under some conditions.

There is no clear link between nitrogen source and TSNAs.

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

What the grower can do. Follow these steps:

- Apply no more nitrogen than is necessary for the crop. Apart from minimizing TSNAs, there are many other good reasons to avoid excessive nitrogen—not the least of which is cost. Excess nitrogen can also cause disease problems and contribute to groundwater pollution, and it does not increase yield.
- If sidedressing, apply sidedressing at the recommended 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. Top as recommended (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.

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

What the grower can do. Availability of labor to cut the crop often limits the grower's choice of harvest date, but as far as possible, harvest at the correct maturity according to the following timetable.

- Burley no later than the recommended 28 days after topping
- Dark air-cured by 35 days after topping
- Dark fire-cured by 49 days after topping

Some early-maturing varieties may require earlier harvest.

Variety

To some extent, there seem to be inherent differences between 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. We do not yet understand the mechanism for these varietal differences, but it appears that KT 204LC often has lower TSNA levels than other varieties. 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. It is unclear if there is any difference in TSNA accumulation among dark tobacco varieties.

What the grower can do. 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.

Best Management Practices for Minimizing TSNAs

TSNA formation is a very complex process, and one cannot consider any of the factors contributing to it in isolation. All of these factors interact, and that is why different treatments sometimes result in TSNA differences and sometimes do not. The following is a list of practices that 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 sidedressing at the recommended four to five weeks after transplanting.
- Top correctly.

- Harvest at correct maturity, ideally four weeks after topping for burley, five weeks for dark air-cured, and seven weeks for dark fire-cured.
- Do not cut wet tobacco.
- Do not house tobacco with free moisture on the leaves.
- Avoid overpacking the barn, and space sticks and plants on sticks evenly.
- Manage air-curing carefully, ensuring adequate but not excessive ventilation, and avoid houseburn.
- Fire dark tobacco no more than necessary.
- Ideally, start firing dark fire-cured tobacco by seven days after housing.
- Do not allow barn temperatures in fire-cured barns to exceed 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 using 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 that specified in the contract.

Safety in Tobacco Production

Mark Purschwitz and John Wilhoit

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 be 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 structure to reduce the climbing around that has to be done, 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, looking 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? 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 accommodated the riders safely and comfortably. 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 rollover 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?

Harvest Field Safety and Health

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

Heat and sun exposure are other obvious hazards that should be discussed with workers. Wearing hats that cover the ears reduces sun exposure that has resulted, over the long term, in high rates of skin cancer among farmers. Hydration is critical; plenty of water should be available at all times, and workers should be encouraged to take breaks and stay hydrated. In the military, field personnel in hot climates are *ordered* to stay hydrated; it is not an option. Problems that can result from excessive heat include heat rash, which is skin irritation from excessive sweating; heat cramps; heat exhaustion, which has symptoms like heavy sweating; rapid breathing; and a fast but weak pulse; heatstroke, which is a life-threatening illness resulting from very high body temperatures and can have 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 rainsuit 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. Needless to say, the consumption of alcohol during hanging operations should be absolutely prohibited.

Stripping and Market Preparation

The same precautions for housing tobacco in traditional barns apply when climbing back in the barns to bulk the tobacco for stripping. The hazards involved with traditional manual stripping operations are minimal, but if some of the newer powered mechanical stripping devices are used, workers need to be protected from moving parts like gears and chains. Hearing protection may be required around powered stalk choppers, which can be very loud. 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 proper dust respirators are necessary to protect the respiratory health of workers and provide a more comfortable working environment. These respirators should be approved by the National Institute for Occupational Safety and Health. N-95 types are available from a number of online safety companies.

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 SMV (slow-moving vehicle) 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. First and foremost, locking hitch pins should always be used to prevent wagons or other trailing equipment from coming unhitched. Safety chains should be used with pickups. 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. Allowing adequate time to cross or pull onto or 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 for liability reasons. 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. Being involved in a serious collision following failure to obey traffic regulations exposes you to 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 ROPS (Roll-Over Protective Structures), which are either roll bar-type frames or cabs with rollover protection built into the structure. Seatbelts should be worn when tractors have ROPS, but even if the operator is not wearing a seatbelt, a tractor with a ROPS is much safer than a tractor without ROPS. Tractors used on hillsides should have wider wheel spacings, 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 them. Helpers should wait until the tractor stops before stepping between tractor and 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 runovers 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.*

Pest 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). Diseases encountered in field production of burley and dark tobacco include black shank, blue mold, target spot, frogeye, brown spot, soreshin, Fusarium wilt, black root rot, angular leaf-spot (wildfire), virus diseases (virus complex, tobacco mosaic, alfalfa mosaic, ringspot, tomato spotted wilt), and bacterial stalk rot (hollow stalk). Diseases such as brown spot and black root rot are found more commonly on dark tobacco than on burley, while blue mold occurs routinely on burley and rarely affects dark tobacco. 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 that will be used 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 operated by the University of Kentucky or the University of Tennessee. Tobacco-related publications from the UK Cooperative Extension service are available at your county Extension office. You can also access information online that can help with identification of disease problems. Web sites provided by the University of Kentucky (http://www.uky.edu/Ag/kpn/kyblue/kyblue.htm) and 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 grow. However, early plantings may suffer from black root rot. On the other hand, planting later to avoid early-season activity by thrips may reduce losses to tomato spotted wilt.

Exclude plant pathogens from the field. Keep plant pathogens out of "clean" fields by sanitizing equipment (especially if you share equipment or farm in several different areas) and shoes and by limiting animals' access to fields. 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 locally-produced transplants or those grown north of Tennessee to avoid problems with blue mold. Plants produced in the Deep South may become exposed to blue mold at their source, and their importation into Kentucky or Tennessee could start an outbreak early in the season.

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 soreshin. Do not set plants that have blue mold —destroy them immediately. Such plants will die, or if they survive they will not thrive and can 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.

Rotate to non-related crops. Crop rotation is a highly effective tool for preventing and managing diseases, particularly those that are soilborne (including nematodes) or 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 be used to reduce disease pressure in fields after a serious disease outbreak; however, longer intervals between susceptible crops, as discussed earlier, are recommended.

Unfortunately, rotation is not effective against all diseases. Diseases caused by pathogens that don't overwinter in soil or on plant debris, like blue mold, are not affected by crop rotation.

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 chapters 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.

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 like 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 be moved into tobacco by insect vectors. By the same token, don't plant tomatoes or peppers in tobacco fields.

Plow cover crops early. This practice will ensure that plant matter decomposes thoroughly before setting time. Soreshin and black root rot can be problems in fields with high levels of partially decomposed organic matter. Heavily manured fields may also 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 pH within recommended ranges during the growing season. Allow pH to drop somewhat during rotational periods to promote rapid decline of *Phytophthora* (black shank) populations in soil. Do not overfertilize, 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.

Harvest in a timely manner and manage barns correctly. Overmature tobacco is more prone to leaf-spotting diseases such as brown spot. Manage humidity levels in barns to avoid houseburn and barn rots.

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

- Do not use products that are not approved for tobacco. By the same token, don't use tobacco-approved products in ways that are not outlined on the products' labels. Pay attention to safety precautions, and observe guidelines for resistance management.
- Apply fungicides preventively or at the latest when first symptoms of disease appear. Most products labeled for tobacco are protectants and must be in place before the arrival of the pathogen to suppress infection. Applications made after a disease has become established will 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 gal/A early (when plants are small) and increase to as much as 100 gal/A 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 canopy.
- Calibrate sprayers for accurate delivery, which will ensure 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. Replacement of nozzles 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.

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; however, many dark varieties are very susceptible to this disease. 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 2) 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 sanitary 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 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, although grass sods seem to reduce populations of *P. nicotianae* to a greater degree than other crops. Legumes and vegetables may promote the buildup of other soilborne pathogens responsible for diseases like soreshin, damping-off, and black root rot.

Field location is an important consideration—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 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, particularly if other practices (good rotation, fungicides) are employed. In Kentucky and Tennessee, we deal primarily with two races of *P. nicotianae* on tobacco, race 0 and race 1. Historically, race 0 tended to be the predominant strain present in most fields of burley tobacco, but extensive use of certain varieties ('L8' hybrids) over time has led to many areas having a mixture of race 0 and race 1.

Burley varieties are available with varying degrees of resistance to both races of the black shank pathogen (see "Selecting Burley Tobacco Varieties" in this guide). However, no variety is completely resistant to black shank. These varieties can be placed into three groups: completely susceptible, partially resistant to races 0 and 1, and those with "near-immunity" to race 0 (10 on the black shank rating scale). No variety possesses "near-immunity" to race 1. Generally speaking, Hybrid 404, HB04P, and NC 2002 are examples of varieties with no resistance to black shank. Partial resistance ranges from low (1-3 on the rating scale) for older varieties like NCBH 129; to moderate (4-6 on the rating scale) for TN 86, TN 90, or KT 200; to high (7 on the rating scale) for KT 204. Varieties such as KY 14 × L8, HB 3307P LC, and 'NC 7' have near-immunity to race 0, owing to their genetic makeup, but low to no resistance to race 1. However, KT 206, KT 209, and KT 210 have near-immunity to race 0 plus high resistance (7-8 on the rating scale) to race 1; KT 206 also is partially resistant to blue mold.

Growers of dark tobacco will find that resistance to black shank is limited in many varieties, although KT D4, KT D6, and KT D8 do have moderate levels of resistance to both races of *P. nicotianae* (see "Choosing Dark Tobacco Varieties for 2011"). New varieties such as PD 7302, PD 7309, and PD 7318 have near-immunity to race 0 but are completely susceptible to race 1, similar to KY 14 × L8. The recently-introduced PD 7305 offers a modest level of race 1 resistance plus very high race 0 resistance.

Field history, in terms of crops grown and previous severity of black shank, should be considered when deciding on a variety to grow. Choose a variety with little or no resistance (0-3 on the rating scale) if planting into fields with no history of disease or where good rotation has been practiced. Varieties with "near-immunity" to race 0 and low resistance to race 1 of *P. nicotianae* are practical if populations of race 1 are not present. Without time-consuming tests, though, it is difficult to say which race of the black shank pathogen is present in a field. The safest bet for burley growers is to assume that both races are present in fields known to be prone to black shank and use varieties with moderate-to-high levels of resistance to race 1 (4-8 on the rating scale) in conjunction with rotation and fungicides. Historically, race 0 has been the predominant pathogen found in areas of dark tobacco production; however, race 1 has been on the increase in recent years. Growers who plant dark varieties like PD 7302, PD 7309, and PD 7318 should be aware that these varieties will likely promote development of race 1 over time.

For suppression of black shank, use products containing mefenoxam (Ridomil Gold or Ultra Flourish) or metalaxyl (MetaStar) (Table 1) in conjunction with resistant varieties (4 or better on the rating scale) and crop rotation. In most cases, fungicides will not provide acceptable control of black shank if applied to varieties with little or no resistance to black shank. Good soil moisture is needed for best performance of these products against black shank because uptake by roots is required for best control of disease. Where black shank has been severe, consider making a preplant application at 1-2 pt/A of Ridomil Gold, 1-3 qt/A of Ultra Flourish, or 4-6 qt/A of MetaStar prior to transplanting. Use a volume of water or fertilizer sufficient for good soil coverage and incorporate into the top 2-4 inches of soil by disking or irrigation. Under light-to-moderate disease pressure, apply fungicides within one-two weeks of transplanting. For extended control of black shank, make a supplemental application (1 pt of Ridomil, 1 qt of Ultra Flourish, or 2 qt of MetaStart) of fungicide at layby OR at first cultivation and again at layby. These applications should be directed toward the soil and incorporated immediately by cultivation. Avoid "over-the-top" applications of fungicide 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. Do not make supplemental applications if more than 1 pt of Ridomil Gold, 1 qt of UltraFlourish, or 2 qt of MetaStar was used at planting. Do not exceed the equivalent of 1.5 lb a.i./A of mefenoxam per season (3 pt of Ridomil Gold, or 3 qt of Ultra Flourish, or 6 qt of MetaStar).

Table 1. Guide to chemicals available for control of tobacco diseases 2011—soil application (field).

Fumigants		Product Rate Per Application[a]	Product Rate Per Season	Target Diseases	Label Notes
Chloropicrin		60-100 lb/A (broadcast)	--	black root rot black shank	Inject to 8-in. depth. Apply when soil temperatures are >55°F and moisture levels are adequate. Apply a minimum of 3 weeks before setting transplants.
		150-500 lb/A (broadcast)	--	soreshin nematodes Fusarium wilt bacterial wilt	
Telone C-17		10.8-17.1 gal/A (broadcast)	--	bacterial wilt black root rot	
Telone C-35		13-20.5 gal/A (broadcast)	--	black shank nematodes	
Non-fumigants					
Ridomil Gold SL	preplant only	1-2 pt	3 pt	black shank	Incorporate into the top 2-4 in. of soil after application by disking or cultivation.
	preplant + layby	1 pt + 1 pt			
	preplant + 1st cultivation + layby	1 pt + 1 pt + 1 pt			
Ultra Flourish	preplant only	1-3 qt	3 qt		
	preplant + layby	1 qt + 1 qt			
	preplant + 1st cultivation + layby	1 qt + 1 qt + 1 qt			
MetaStar 2E	preplant only	4-6 qt	6 qt		
	preplant + layby	2 qt + 2 qt			
	preplant + 1st cultivation + layby	2 qt + 2 qt + 2 qt			

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

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 Kentucky 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. By-products from decomposition of rye and barley residues are also believed to increase the susceptibility of tobacco to the black root rot fungus, making these crops a risky choice for cover crops in areas with a history of the disease. Avoid planting in cool soils and excessive use of lime (keep soil pH between 6.0 and 6.4 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 (Table 3), but their use may not be practical for many producers.

Blue mold. Blue mold has caused serious losses in certain years when cool and rainy conditions have prevailed, particularly early in the season. The blue mold pathogen, *Peronospora tabacina*, does not overwinter normally in Kentucky or Tennessee 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 begin normally from introductions of *P. tabacina* from areas outside these states where *P. tabacina* is present year-round. In rare cases, the blue mold pathogen may overwinter in Kentucky and Tennessee 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 transplants that are free of the disease; avoid transplants produced south of Tennessee. If planting into areas that are prone to blue mold, select a variety with partial resistance to it (see chapters on variety selection). Two varieties, NC 2000 and NC 2002, have moderate-to-high resistance to blue mold, while KT 206 and TN 90 have low-to-

Table 2. Guide to chemicals available for control of tobacco diseases in the field, 2011—foliar applications.

Chemical	Product Rate Per Application[a]	Product Rate Per Season	PHI[b] (days)	Target Diseases	Label Notes
Agricultural Streptomycin, Agri-Mycin 17, Firewall	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 (Dithane DF, Manzate ProStick, 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.
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 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	31.2 fl oz	0	target spot frogeye blue mold	Begin applications before blue mold symptoms appear. Continue sprays on a 7-14 day schedule (use a shorter spray interval when conditions favor disease). If blue mold is present in the field, apply Forum, tank-mixed with mancozeb, prior to using Quadris. Do not make back to back sprays. Alternate with different fungicide labeled for tobacco. Can be used up to the day of harvest; however, due to a lack of post-topping options for product rotation, make only one application after topping. Do not mix with EC-type pesticides or with sucker control materials.

[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.*

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 2. 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, or visit the KY Tobacco Disease Information Page (http://www.uky.edu/Ag/kpn/kyblue/kyblue.htm) or the North American Plant Disease Forecast Center (http://www.ces.ncsu.edu/depts/pp/bluemold). Once blue mold has been reported or threatens an area, fungicides should be applied at regular intervals as long as conditions favor development of blue mold to minimize losses.

Quadris is labeled for control of blue mold, frogeye, and target spot. While not as effective against blue mold as Forum + Dithane, 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. If blue mold is present in a field, apply Forum tank-mixed with Dithane DF, Manzate, and Penncozeb (mancozeb) 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 + mancozeb) 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 material 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 include Forum, 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 2).

Actigard remains one of our best options for blue mold control. It is a systemic product that functions by inducing plant defenses and is thus 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. Use another fungicide if blue mold threatens tobacco less than the recommended height 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 is labeled for control of blue mold but should not be relied upon to manage this disease. Resistance to mefenoxam (Ridomil Gold and 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 spacings, 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 and target 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, has become increasingly prevalent, and yield losses of 50% or more have been observed in some areas. High humidity and moderate temperatures favor this disease, making target spot a serious problem 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. Additionally, do not underfertilize or overfertilize 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 2). However, Quadris cannot be applied back-to-back—unrelated fungicides must be applied between Quadris applications. Although Manzate and Penncozeb are only slightly effective against frogeye and target spot, they are the only choices for this purpose at this time. Rates and timing of Quadris applications depend on many factors, such as the level of control of leaf-spots desired, field history, rainfall, and the type of tobacco grown. Generally, a rate of 8 fl oz/A provides adequate control of fungal spots while minimizing the severity of flecking caused by Quadris. A ten-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 24-36 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. In fields that have experienced severe outbreaks of the disease, long (five-plus years) rotations may be needed to reduce damage to economically acceptable levels, due to the persistent nature of *F. oxysporum* in soil. 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 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 overfertilized. 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

Table 3. Guide to the relative response of weeds to herbicides.[1]

	Crabgrass	Fall Panicum	Foxtails	Johnsongrass (seedling)	Johnsongrass (rhizome)	Shattercane (Wild Cane)	Yellow Nutsedge	Black Nightshade	Cocklebur	Galinsoga, Hairy	Jimsonweed	Lambsquarters	Morningglory	Pigweeds	Common Ragweed	Ragweed, Giant (Horseweed)	Smartweed	Velvetleaf
Command	**G**	**G**	**G**	F	P	F	P	P	F	F	F	**G**	P	P	**G**	F	F	**G**
Devrinol	**G**	**G**	**G**	F	P	P	P	P	N	F	N	F	N	F	F	N	P	P
Prowl	**G**	**G**	**G**	**G**	P	F	N	N	N	P	N	**G**	P	**G**	P	N	F	F
Spartan	F	F	F	P	P	P	**G**	**G**	F	F	**G**	**G**	**G**	**G**	P	P	**G**	F
Spartan Charge	F	F	F	P	P	P	**F-G**	**G**	F	F	**G**	**G**	**G**	**G**	P	P	**G**	F
Spartan + Command	**G**	**G**	**G**	F	P	F	**G**	**G**	F	**G**	**G**	**G**	**G**	**G**	**G**	F	**G**	**G**
Poast	**G**	**G**	**G**	**G**	F	**G**	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 own conditions, products should not necessarily b e changed as a result of the information in the table.*

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 also 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 earlier chapters on variety selection). Control of insect vectors gives variable (and unpredictable) levels of control of aphid-transmitted viruses or TSWV (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 less 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

Fumigants. Several fumigants are registered for use on tobacco for preplant suppression of soilborne pathogens and nematodes, but they should be considered a measure of last resort. Nematodes have not been a serious problem in Kentucky or Tennessee, and the use of products such as Telone C-17 or C-35 is not warranted under most circumstances due to high material costs and expensive custom application. Chloropicrin used as a preplant soil treatment will reduce populations of *P. nicotianae, Rhizoctonia, Fusarium, Pythium,* and *Thielaviopsis,* giving fair control of disease. As with soil nematicides, chloropicrin is expensive and must be applied with specialized equipment and will 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, 2010. 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.

Weed Control

Weeds can impact tobacco production by reducing yield and interfering with crop harvest. 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 3 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 are beneficial for initial weed control by destroying early season weeds that have emerged before transplanting. Field cultivation and hand-hoeing are also traditional methods used for obtaining good weed control post-transplant. In more recent years effective herbicide control options have decreased 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 4.

Crop Rotations. Use of certain herbicides on a previous crop can limit rotational crops that can be planted in the fall or in the next crop-production season. For example, when corn has been planted and atrazine was applied for weed control during the previous season, there is a possibility that tobacco could be injured the year following application. Tobacco can also be damaged by residual carryover from some pasture or forage crop herbicides. Therefore, consult the label of herbicides used

to determine whether there is a risk to planting tobacco in fields that were used to grow other grain or forage crops. General rotational crop guidelines for herbicides available in grain crops can be found in University of Kentucky Extension bulletin *Weed Control Recommendations for Kentucky Grain Crops* (AGR-6), or the University of Tennessee Extension bulletin *2011 Weed Control Manual for Tennessee* (PB 1580).

Also, be familiar with label guidelines and restrictions when applying tobacco herbicides and there is a desire to plant a cover crop or different rotational crops the following season. Limitations for some rotational crops are highlighted within the remarks for each herbicide listed in Table 4.

Insect Control

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, so timely field checks and use of treatment guidelines will allow early detection and assessment of problems so that sound pest management decisions can be made.

Pre-Transplant: Soil Applications

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

Transplant: Tray Drench Applications

Admire Pro 4F (and generic versions of this product that contain the active ingredient imidacloprid), Belay, 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. Agitate or mix the

Table 4. Herbicides recommended for use in tobacco fields.

Herbicide	Weeds Controlled	Remarks and Limitations
Before Transplanting—Burn-down Herbicides for Use in Conservation Tillage		
Gramoxone Inteon 2S 2.4 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	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 burn-down. Do not graze treated areas or feed treated cover crops to livestock.
Before Transplanting—Soil-applied Herbicides		
Devrinol 50DF 2 lb/A or **Devrinol 2EC** 2 qt/A (*napropamide* 1 lb ai/A)	Crabgrass, fall panicum, foxtails	Apply before transplanting and incorporate immediately, preferably in same operation. Follow incorporation directions on label. To avoid injury to crops not specified on the label, do not plant 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)	Crabgrass, fall panicum, foxtails, lambsquarters, pigweeds	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.
Command 3ME 2 to 2.67 pt/A (*clomazone* 0.75 to 1 lb ai/A)	Crabgrass, fall panicum, foxtails, jimsonweed, lambsquarters, common ragweed, velvetleaf	Apply COMMAND 3ME as a soil-applied treatment prior to transplanting or to 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.

continued on next page

Table 4. Herbicides recommended for use in tobacco fields.		
Herbicide	**Weeds Controlled**	**Remarks and Limitations**
Spartan 4F 8 to 12 fl.oz/A (*sulfentrazone* 0.25 to 0.375 lb ai/A)	Black nightshade, jimsonweed, lambsquarters, morningglories, pigweeds, smartweed, yellow nutsedge	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.
Spartan Charge 10.2 to 15.2 fl.oz/A (*carfentrazone* 0.028 to 0.42 lb ai/A + *sulfentrazone* 0.25 to 0.38 lb ai/A)	Black nightshade, jimsonweed, lambsquarters, morningglories, pigweeds, smartweed	Use the higher rate of SPARTAN CHARGE when weed pressure is heavy with morningglory or yellow nutsedge. Apply from 14 days before up to 12 hours prior to transplanting tobacco as a soil surface treatment or preplant incorporated (less than 2 inches deep). Perform all cultural practices for land preparation, fertilizer/fungicide incorporation, etc. prior to application of SPARTAN CHARGE. If the soil must be worked after application but prior to transplanting, do not disturb the soil to a depth greater than 2 inches. Temporary stunting or yellowing of tobacco and localized leaf burns may be observed under some conditions with this treatment. Unacceptable crop injury can occur if applied post-transplant. Rotational crops that may be planted include soybeans or sunflowers anytime; field corn, wheat, barley, or rye after 4 months; alfalfa, popcorn, sweet corn, and oats after 12 months; and sorghum (for rates above 10.2 fl.oz/A) after 18 months. See label for rotation guidelines with other crops.
After Transplanting—Postemergence Herbicides		
Poast 1.5E 1.5 pt/A (*sethoxydim* 0.28 lb ai/A) + Oil Concentrate 2 pt/A	Crabgrass, fall panicum, foxtails, Johnsongrass, shattercane	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 Jjohnsongrass 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.

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 newly introduced product, Coragen. 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 galA 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 important ensure that the solution is evenly distributed for effective insect control. For application equipment that has minimal agitation, such as tobacco transplanters, give proper attention to mixing. Keep the water suspension agitated or mix regularly to avoid settling in the transplant tank. Adverse growing conditions may cause a delay in the uptake of Admire (or a generic equivalent) into the plants and a delay in control.

Premix 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 infested plants in a field determines whether or not a control measure is justified. Pest numbers can vary due to factors such as weather, natural enemies, and transplant date. Early-set fields are prone to attack by flea beetles and tobacco budworms, while late-set fields are at greater risk to 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 5 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.

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

Table 5. Insect management calendar—treatment guidelines for key tobacco insect pests.

Insect	Treatment Guidelines
1-4 weeks after transplant	
Cutworms	Five or more freshly cut plants per 100 plants checked.
Flea Beetles	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% 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 (1inch or longer) per 50 plants. Do not count hornworms with white cocoons on their backs.

Table 6. Pre-transplant soil applications for tobacco fields.

Pre-plant Insecticides	Rate/Acre	Labeled Pests
Lorsban 4E (chlorpyrifos), Chlorpyrifos, Warhawk	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 7. Tray-drench application of insecticides.

Insecticide	Rate	Comment
Admire 2F (and generic formulations of imidicoprid 2F)	1 fl oz/1,000 plants	Aphids, flea beetles, wireworms (high rate)
	1.4 to 2.8 fl oz/1,000 plants	
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
Belay 16 WSG	5 oz/A	Flea beetles
	10 oz/A	Aphids
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 8. Transplant—Water application of insecticides.

Insecticide	Rate	Comment
Admire 2F (and generic formulations of imidacloprid 2F)	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 (42.8%)	0.6 to 1.2 fl oz/1,000 plants	
Coragen SC	5 to 7.5 fl oz	Budworms hornworms
Orthene 97	3/4 lb/A	Flea beetles, cutworms
Belay 16 WSG	5 oz/A	Flea beetles, aphids
	10 oz/A	
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

Tobacco Aphids

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% or more of the plants that are examined.* Thorough coverage with sprays directed to the underside of leaves at the top of the plant is essential to obtain satisfactory aphid control. Aphid infestations tend to be higher in later-set fields, where more than minimum recommended rates of nitrogen are used, and when topping is delayed.

Table 9. 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
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	2.5 to 4 oz	
Restricted Use Pesticides		
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	
Lannate 90 SP	½ lb	14
Voliam xpress	5 to 9 fl oz	40

Budworms

Budworms chew rounded holes in developing leaves of the upper third of the plant. Infestations tend to be greatest in the earliest-set fields in an area. Moths lay single eggs so infestations are scattered randomly over a field. Examine the bud area carefully for the black ground pepperlike 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 1-1/4 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 feeding actively. Use 25 to 50 gal of water/A and spray in the morning or early evening when the bud area is open and the budworms are most exposed to sprays. Use the highest labeled rates for heavy populations.

Table 10. Budworms.

Insecticides	Rate/A	Harvest Interval (Days)
Agree WG (3.8% Bt aizawai)	1 to 2 lb	0
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	3.5 to 7.5 fl oz	1
Dipel 10 G	5 to 10 lb	0
Dipel DF	½ to 1 lb	
Dipel ES	1 to 2 pt	
Lepinox WDG	1 to 2 lb	
Orthene 97	3/4 lb	3
Sevin 80S	1-1/4 lb	0
Voliam flexi	4 oz	14
XenTari DF	½ to 2 lb	0
Restricted Use Pesticides		
Brigade 2EC	2.56 to 6.4 fl oz	Do not apply later than layby
Capture LFR	3.4 to 8.5 fl oz	
Denim 0.16 EC	8 to 12 fl oz	14
Lannate SP	½ lb	
Voliam xpress	5 to 9 fl oz	40
Warrior 1 CS	1.9 to 3.8 fl oz	

Hornworms

Hornworms eat large amounts of tobacco foliage. The first brood appears in June. A second, usually much larger, 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 1-1/2 inches in length will greatly reduce yield loss. Hornworms with white egglike 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% 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 a short residue insecticide if necessary to prevent taking significant numbers to the barn. There are no treatments to control hornworms effectively on housed tobacco.

Flea Beetles

Tobacco flea beetles are present in every field each season. Damage tends to be most severe in fields that are set first, especially following a mild winter when beetle survival is greatest. Flea beetles move frequently, chewing small round holes (shot holes) in the leaves. Extensive damage can occur when beetles feed in the bud of the plant. This injury can add to transplant stress and slow plant establishment. Flea beetles can be controlled with systemic insecticides applied in the transplant

Table 11. Hornworms.		
Insecticides	**Rate/A**	**Harvest Interval (Days)**
Agree WG (3.8% Bt aizawai)	1 to 2 lb	0
Biobit HP (6.4% Bt kurstaki)	½ to 1 lb	
Biobit F (6.4% Bt kurstaki)	1 to 4 pt	
Coragen	3.5 to 7.5 fl oz	1
Dipel 10 G	5 to 10 lb	0
Dipel DF	1/2 to 1 lb	
Dipel ES	½ to 1 pt	
Javelin WG	1/8 to 1-1/4 lb	
Lepinox WDG	1 to 2 lb	
Orthene 97	½ lb	3
Sevin 80S	1-1/4 lb	0
Voliam flexi	4 oz	14
XenTari DF	½ to 2 lb	0
Restricted Use Pesticides		
Brigade 2EC	2.56 to 6.4 fl oz	Do not apply later than layby
Capture LFR	3.4 to 8.5 fl oz	
Denim 0.16 EC	8 to 12 fl oz	14
Lannate SP	½ lb	
Voliam xpress	5 to 9 fl oz	40
Warrior 1 CS	1.9 to 3.8 fl oz	

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. Established plants rarely need protection from this insect.*

Occasional Pests

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

Cutworms may be present in tobacco fields because of early season weed growth. Often these insects are relatively large by the time tobacco is set in the field. Cutworms feed at the base of transplants and can cut them off at ground level. 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, Brigade, Brigadier, Orthene 97, Warrior 1 CS, or Voliam xpress can be used as a broadcast spray.

Table 12. 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	
Restricted Use Pesticides		
Brigade 2EC	2.56 to 6.4 fl oz	Do not apply later than layby
Capture LFR	3.4 to 8.5 fl oz	
Lannate 90 SP	½ lb	14
Voliam xpress	5 to 9 fl oz	40
Warrior 1 CS	1.92 to 3.84 fl oz	

Grasshoppers usually remain in hayfields and along waterways, but under dry conditions they may move from these into tobacco. Treatment of field borders to prevent mass migration into the field should be considered. 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, Brigadier, Orthene, Provado, Sevin 80S, Warrior, Voliam flexi, or Voliam xpress may be used if Japanese beetles are causing significant damage.

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, Brigade, Brigadier, Orthene, Voliam xpress 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.

Table 13. Grasshoppers.		
Insecticides	**Rate/A**	**Harvest Interval (Days)**
Orthene 97	1/4 lb	3
Restricted Use Pesticides		
Brigade 2EC	2.56 to 6.4 fl oz	Do not apply later than layby
Capture LFR	3.4 to 8.5 fl oz	
Lannate 90 SP	½ lb	14
Voliam xpress	5 to 9 fl oz	40
Warrior 1 CS	1.92 to 3.84 fl oz	

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