Recommendations for the use of agricultural chemicals are included in this publication as a convenience to the reader. The use of brand names and any mention or listing of commercial products or services in this publication does not imply endorsement by North Carolina State University nor discrimination against similar products or services not mentioned. Individuals who use agricultural chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage regulations and examine a current product label before applying any chemical. For assistance, contact your local Cooperative Extension center.

A PRECAUTIONARY STATEMENT ON PESTICIDES

Pesticides must be used carefully to protect against human injury and harm to the environment. Diagnose your pest problem, and select the proper pesticide if one is needed. Follow label use directions, and obey all federal, state, and local pesticide laws and regulations.

This publication is also available at
content.ces.ncsu.edu/flue-cured-tobacco-information

The drawing of the tobacco plant on the inside rear cover is reprinted with permission from Alliance One International.

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2020 FLUE-CURED TOBACCO GUIDE

NC STATE EXTENSION

2020 FLUE-CURED TOBACCO GUIDE

NC STATE EXTENSION

Much of the research and extension information contained in this publication was funded by the grower-supported North Carolina Tobacco Research Commission. Funding is awarded annually to tobacco faculty at NC State University based on the present and future needs of the tobacco industry. Tobacco growers have the opportunity to continue their support of this important program through a referendum every six years. The last referendum, held in November 2015, was approved by 94.5% of the voters. For more information, contact the North Carolina Agricultural Research Service, NC State University, Box 7643, Raleigh, NC 27695-7643, or call 919-515-2717.

The printing of the *2020 Flue-Cured Tobacco Guide* is supported totally by a grant from the North Carolina Tobacco Foundation Inc. The Foundation also receives contributions and provides funds to supplement public appropriations for quality research and extension programs at NC State University for the benefit of the entire tobacco industry. For more information, write to Sonia Murphy, President, North Carolina Tobacco Foundation, Inc., Box 7645, Raleigh, NC 27695-7645, or call 919-515-2000.

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Carolina Farm Credit, ACA Headquarters
Hail & Cotton Inc
Helena Agri-Enterprises, LLC
Independent Leaf Tobacco Co., Inc.
NC Farm Bureau Foundation, Inc.
Tobacco Associates
Yara International, ASA

THE TOBACCO PLANT

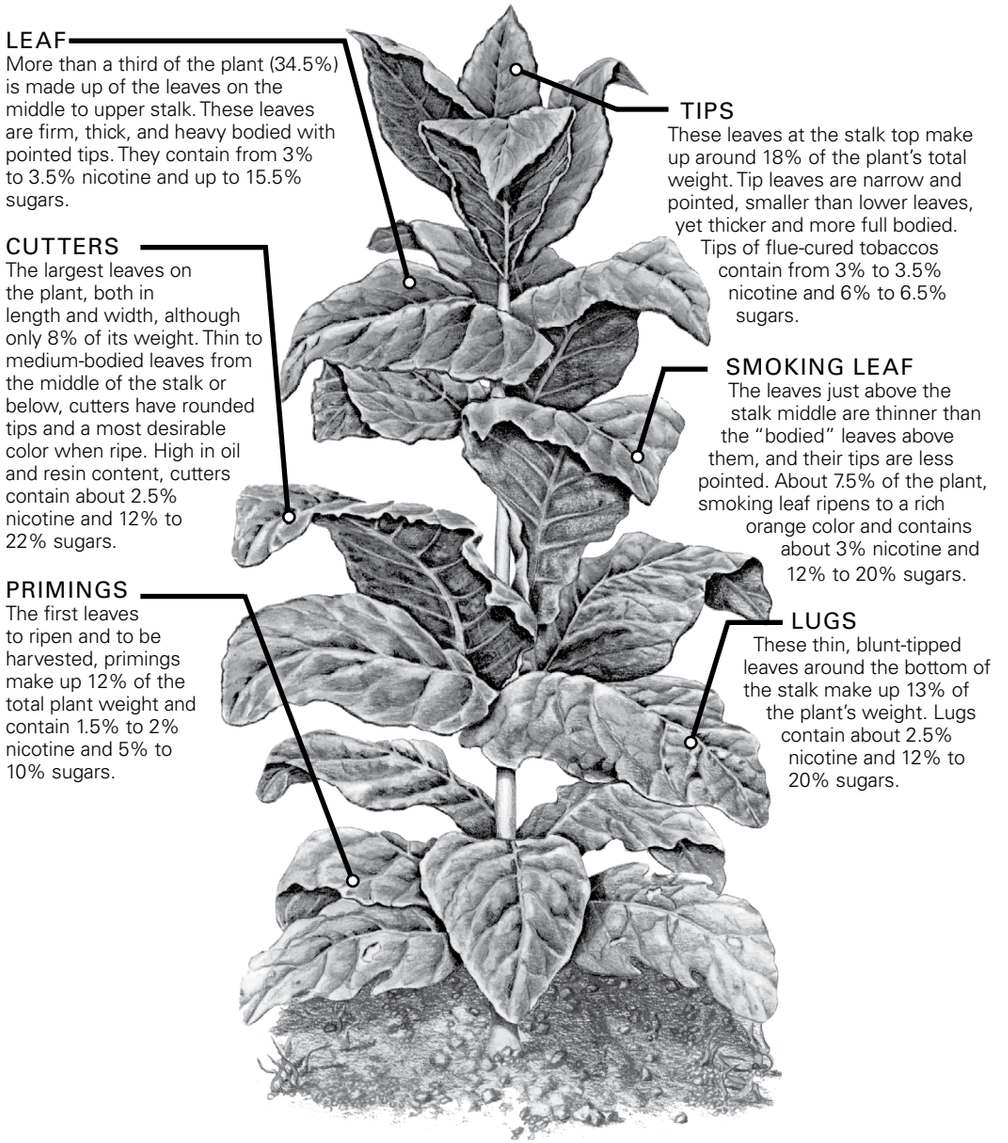

Figure 1. Characteristics of tobacco leaves based on stalk position

More than 2,500 different chemical compounds have been identified in the leaves of commercially grown tobacco. The most important of these is nicotine, of course. But the various sugar levels found in the plant also play a vital role when different tobaccos are blended. The nicotine and sugars in the leaves will vary according to soil, light conditions, moisture, and temperature, as well as stalk position.

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EXTENSION PERSONNEL WORKING WITH TOBACCO

Tobacco growers in North Carolina are fortunate to have an Extension agent with tobacco responsibilities in each tobacco-producing county. These agents are supported by research and Extension faculty in the College of Agriculture and Life Sciences at North Carolina State University. The following are the county Cooperative Extension personnel with tobacco responsibilities as of December 2, 2019.

COUNTY	NAME	TELEPHONE
Alamance	Dwayne Dabbs	336-570-6740
Alexander	Allison Brown	828-632-4451
Beaufort	Rod Gurganus	252-946-0111
Bertie	Jarette Hurry	252-794-5317
Bladen	Matthew Strickland	910-862-4591
Brunswick	Mark Blevins	910-253-2610
Caldwell	Seth Nagy	828-757-1290
Carteret	Mike Carroll	252-728-8421
Caswell	Joey Knight	336-694-4158
Chatham	Ashley Robbins	919-542-8202
Chowan	Matt Leary	252-482-6585
Columbus	Lydia Miles	910-640-6605
Craven	Mike Carroll	252-633-1477
Cumberland	Kenny Bailey	910-321-6875
Davidson	Troy Coggins	336-242-2081
Davie	Marsha McGraw	336-751-6297
Duplin	Della King	910-296-2143
Durham	Darnell Parker, Jr.	919-560-0526
Edgecombe	Art Bradley	252-641-7815
Forsyth	Tim Hambrick	336-703-2850
Franklin	Charles Mitchell	919-496-3344
Gates	Paul Smith, Jr.	252-357-1400
Granville	Gary Cross	919-603-1350
Greene	Grayson Wells	252-747-5831
Guilford	Anna-Beth Williams	336-375-5876
Halifax	Arthur Whitehead	252-583-5161
Harnett	Brian Parrish	910-893-7530

Hertford	Stephanie Parker-Helmkamp	252-358-7822
Hoke	Howard Wallace II	910-875-3461
Iredell	Laura Elmore	704-878-3153
Johnston	Bryant Spivey	919-989-5380
Jones	Jacob Morgan	252-448-9621
Lee	Mitch Williams	919-775-5624
Lenoir	Steve Killette	252-527-2191
Martin	Lance Grimes	252-792-1621
Montgomery	Lori Ivey	910-576-6011
Moore	Kelly McCaskill	910-947-3188
Nash	Maryanna Waters	252-459-9810
Northampton	Craig Ellison	252-534-2711
Onslow	Melissa Huffman	910-455-5873
Orange	Mart Bumgarner	919-245-2050
Pamlico	Daniel Simpson	252-745-4121
Pender	Mark Seitz	910-259-1235
Person	Gary Cross	336-599-1195
Pitt	Carrie Ortel	252-902-1702
Randolph	Blake Szilvay	336-318-6000
Richmond	Anthony Growe	910-997-8255
Robeson	Mac Malloy	910-671-3276
Rockingham	Will Strader	336-342-8230
Sampson	Hunter Rhodes	910-592-7161
Scotland	Randy Wood	910-277-2422
Stokes	Tim Hambrick	336-593-8179
Surry	Tim Hambrick	336-401-8025
Vance	Paul McKenzie	252-438-8188
Wake	Emily Mueller	919-250-1096
Warren	Paul McKenzie	252-257-3640
Washington	Jalynne Waters	252-793-2163
Wayne	Daryl Anderson	919-731-1520
Wilkes	John Cothren	336-651-7331
Wilson	Norman Harrell	252-237-0111
Yadkin	Tim Hambrick	336-679-2061

1. U.S. FLUE-CURED TOBACCO: SITUATION AND OUTLOOK

Blake Brown
Professor and Extension Economist, Agricultural and Resource Economics

The August 2019 forecast for U.S. and N.C. flue-cured tobacco production was for 315 million and 244 million pounds, respectively. Hurricane Dorian reduced 2019 production, with the October 2019 forecast for the U.S. and N.C. being 274 million and 212 million pounds, respectively. This is the lowest production and acreage in more than 100 years (Figure 1-1).

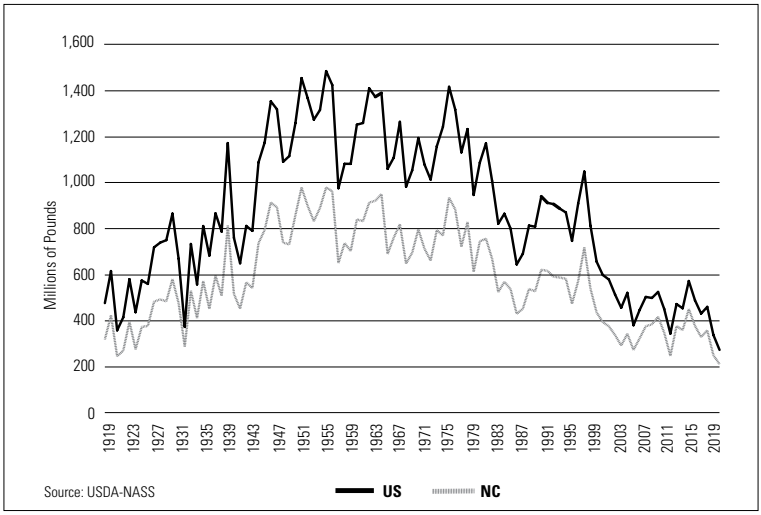

Figure 1-1. U.S. and N.C. Flue-Cured Tobacco Production

Severe reductions in demand stem from many sources including the Family Smoking Prevention and Tobacco Control Act of 2009, which raised the federal excise tax by $1 per pack, numerous increases in state and local excise taxes, comprehensive policies preventing smoking in most public places, the introduction of alternative nicotine delivery methods (e.g., vaping), and the general downward trend in consumption of tobacco products that began in the United States more than 35 years ago and more recently in other countries. A bright spot in global demand for U.S. flue-cured tobacco had been exports to China, which had increased from near zero prior to 2004 to almost 74 million pounds in 2013. But the trade war with China halted imports of U.S. tobacco by China, causing U.S. production to plunge to its current low level. Extensive policy intervention in the U.S. as well as in other countries make speculation regarding the future outlook for flue-cured both difficult and risky.

Leaf Export Markets

With the exception of perhaps one year, more of U.S. flue-cured production has been exported than used domestically for over a decade. The European Union (EU-28) has traditionally been the largest importer of U.S. tobacco. China imported very little U.S. tobacco until after the end of the federal tobacco program in 2004. However China quickly grew to the largest single country importer of U.S. tobacco. Figure 1-2 shows the top ten importing countries for U.S. unmanufactured tobacco (all types). China imported more than $160 million (USD) worth of unmanufactured tobacco followed by Germany at $140 million and Japan at $83 million. Note that Russia, Indonesia, and Turkey are the third, fourth, and fifth ranked importers of U.S. unmanufactured tobacco in terms of value.

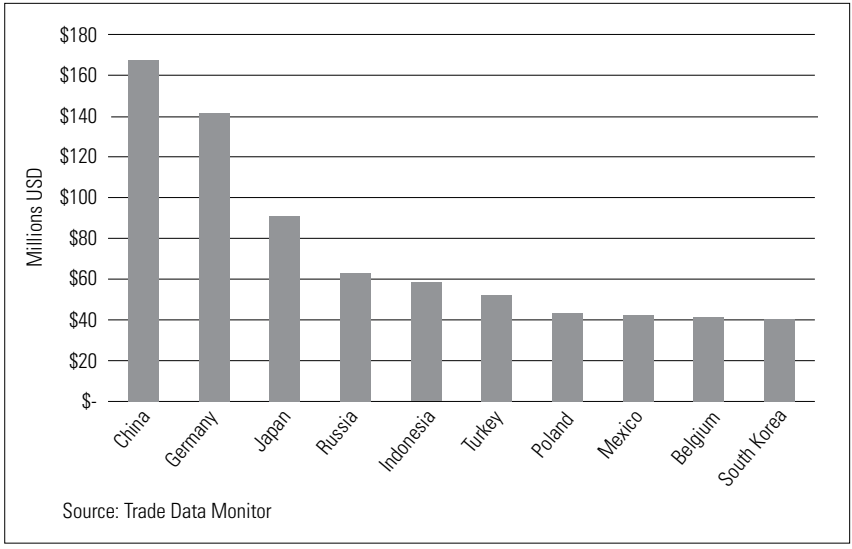

Figure 1-2. Value of 2017 Imports of U.S. Unmanufactured Tobacco

The loss of the Chinese market deals a severe blow to U.S. exports of flue-cured tobacco. In 2017, the United States exported more than 62 million pounds (farm sales weight) of flue-cured tobacco to China. This was 12.8 percent of U.S. production of 460 million pounds of flue-cured in 2017. In 2018, the U.S. exported 59 million pounds to China (Figure 1-3). In 2019, U.S. exports of flue-cured tobacco for January–August were only 513 thousand pounds, down from 59.3 million pounds in the same period of 2018. With domestic demand and export demand from developed countries in decline, demand from China was a rare bright spot for demand for U.S. tobacco. Will China resume purchases of U.S. tobacco if the trade dispute between the U.S. and China is settled? Some in the industry say yes while others are skeptical. Brazil's production of flue-cured has increased to meet increased demand from China. Clearly the danger exists that Chinese manufacturers will not resume purchases of U.S. leaf after having adapted to using less expensive Brazilian leaf.

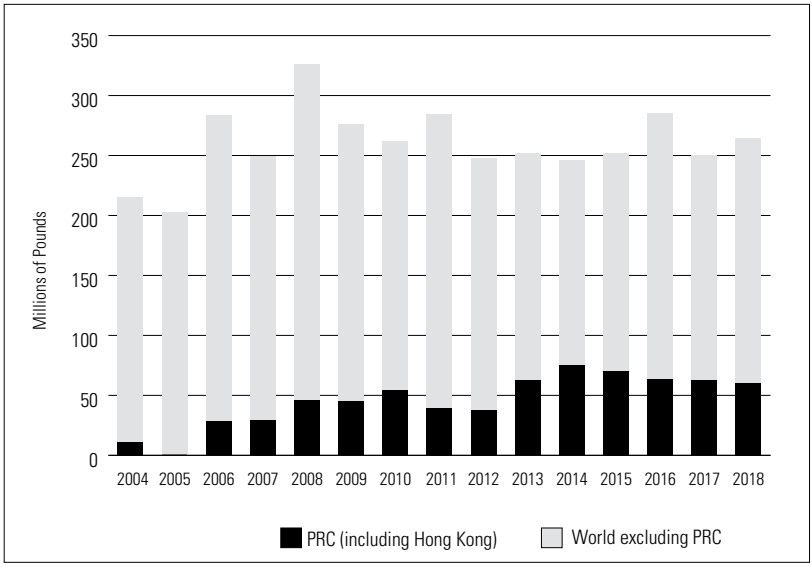

Figure 1-3. U.S. Exports of Flue-Cured Tobacco (Unmanufactured, Farm Sales Weight)

The data on global import of U.S. tobacco highlights the importance of servicing and pursuing leaf demand in traditional markets like Germany and Japan (Figure 1-2). Also important are potential growth markets like Indonesia. Cigarette consumption in Indonesia is declining due to health concerns and increases in excise taxes. But premiumization could lead to increased demand for U.S. tobacco in cigarette blends. Premiumization occurs where demand for premium products increases, in particular where consumer incomes are growing such that consumers want higher quality products. Growth in demand for U.S. tobacco in China was attributed in part to growth in premium cigarette brands that included more high quality tobacco (e.g., U.S. flue-cured) in their blends. IBIS noted that "in certain emerging markets, demand for premium cigarettes has increased, driven primarily by rising disposable income levels" (IBISWorld Industry Report Global Cigarette & Tobacco Manufacturing October 2018, p.15).

Sampoerna, a subsidiary of Philip Morris International, is the largest cigarette manufacturer in Indonesia. According to Euromonitor International (2019) Sampoerna is expected to focus on growing premium brands. Japan Tobacco, with a much smaller market share, has recently made inroads in the Indonesian cigarette market. The Asia Pacific region is the largest global cigarette market (Figure 1-4). Volume sales are declining but premiumization is present in most markets.

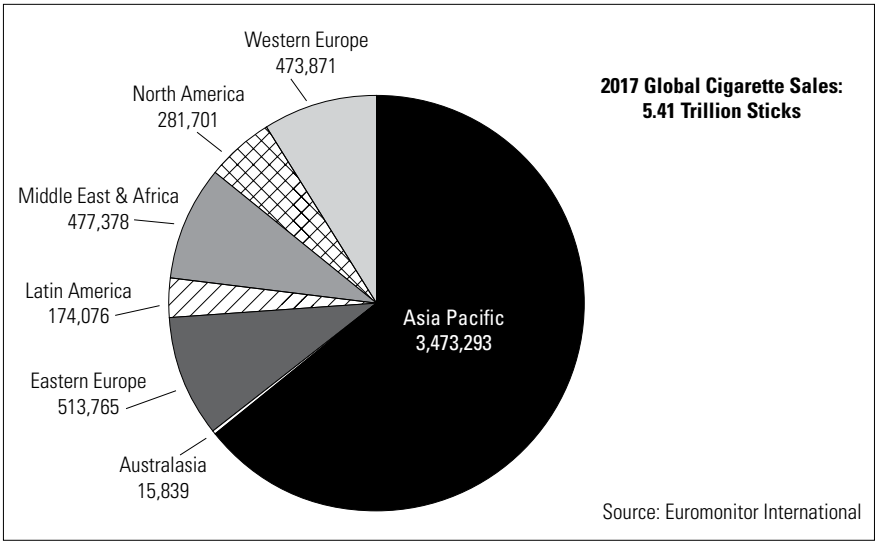

Figure 1-4. 2017 Global Cigarette Sales by Region (Million Sticks)

New Nicotine Delivery Devices

Vaping had been on the rise in the United States, with the number of people vaping rising to 9.6 million in 2018 and the number people smoking declining to 33.9 million. However, teen vaping and a number of deaths tied to vaping, in many cases black market or non-tobacco products, has led to increased scrutiny of vaping. Concerns about vaping may slow or reverse its growth. One possible effect could be a slowing of smokers switching from combustible cigarettes to vaping. Another possible effect could be that tobacco consumers move toward heat-not-burn products, just introduced in the United States this autumn. For tobacco growers, any trend away from vaping toward heat-not-burn or traditional combustibles, could slow the erosion in domestic demand for leaf. However, the effect will likely be small. Nicotine solutions for vaping products are largely sourced from China or India where inexpensive leaf is used in nicotine extraction. Increased regulation of vaping products by FDA is almost certain. Juul Labs, owned in part by Altria, favors categorywide regulation to curb teen use.

Philip Morris International's heat-not-burn product, IQOS, began sales in the United States in September 2019. FDA authorized its sale but is still assessing PMI's application to sell IQOS as a modified risk tobacco product. While heat-not-burn products, unlike vaping products, contain leaf tobacco, the quantity used per stick is much less than that used in a combustible cigarette—less than 40 percent of the amount of leaf contained in a combustible cigarette. How much of the tobacco in the IQOS product is U.S. tobacco remains a critical unknown.

According to IBISWorld, U.S. tobacco products market revenues were almost $46 billion with profits of $19.4 billion in 2018. Combustible cigarettes had U.S. market share of 54.8 percent, and e-vapor products had grown to 9.6 percent of the market (Figure 1-5).

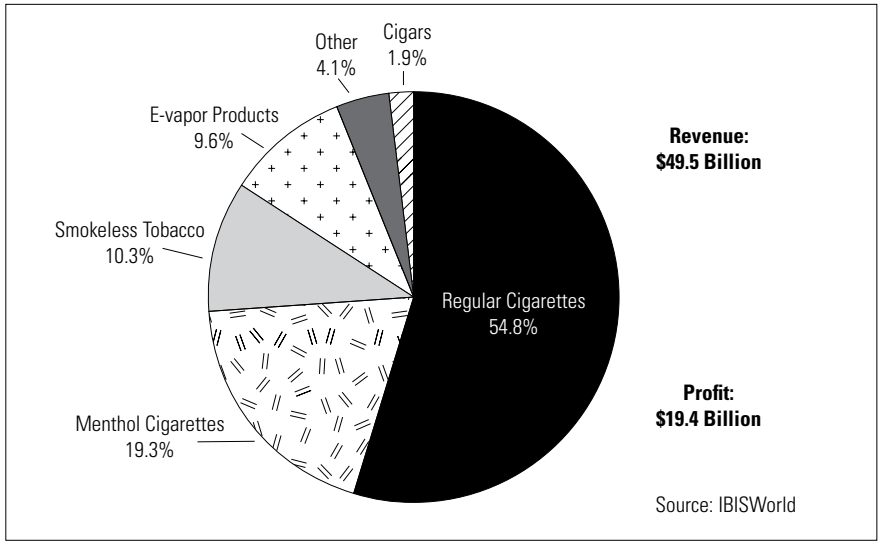

Figure 1-5. U.S. Tobacco Products Market: 2018 Market Segmentation

Impact on Tobacco Farmers

Could U.S. flue-cured tobacco production return to 2017 levels? The best case scenario would be that the trade negotiations between the United States and China are successful so that China returns to its previous purchase levels of U.S. tobacco, concerns about vaping slow the erosion of the domestic combustibles market, and Asian markets continue growth in premium brand cigarettes so that they purchase more U.S. leaf. Unless China buys the current excess inventories of U.S. flue-cured tobacco ahead of the 2020 season larger contracted production in 2020 seems unlikely. A more likely scenario may be that U.S. production rebounds some from the low 2019 level with China returning to some level of U.S. purchases but then gradually declines as the combustibles markets continues its decline.

Regardless of the trade issues, developed-country markets for tobacco continue to be in decline. New nicotine delivery technologies all contain lower levels of leaf than combustible cigarettes. The best hope for slowing the erosion in demand for U.S. flue-cured would be the success of heat-not-burn products with a high U.S. tobacco content and further penetration of Asian markets where growth in premium brand combustibles increases demand for high quality tobacco.

Table 1-1. Flue-cured tobacco—machine harvest—eastern North Carolina: 2020 estimated costs per acre

	Unit	Quantity	Price or Cost/Unit	Total Per Acre	Your Farm
1. GROSS RECEIPTS					
Stalk position		Yield	Price/lb.		
Lugs	lb.	0.00	$0.00	$0.00	
Cutter	lb.	0.00	$0.00	$0.00	
Leaf	lb.	0.00	$0.00	$0.00	
Tips	lb.	0.00	$0.00	$0.00	
Total receipts:				$0.00	
2. VARIABLE COSTS					
Plants (greenhouse)	thou	6.00	$40.00	$240.00	
Multipurpose fumigation	gal	10.50	$17.13	$179.87	
Fertilizer					
9-45-15 Transplant Starter	lbs.	18.00	$1.05	$18.90	
0-0-50 Potassium Sulfate	cwt	2.60	$32.18	$83.67	
30% Nitrogen Solution	cwt	2.30	$14.13	$32.50	
Lime (prorated)	ton	0.33	$51.00	$16.83	
Pest Control*	acre	1.00	$253.19	$253.19	
Sucker Control	acre	1.00	$187.53	$187.53	
Scouting	acre	1.00	$20.00	$20.00	
Hauling	lb.	2,500.00	$0.05	$125.00	
Cover crop	acre	1.00	$25.00	$25.00	
Curing fuel	lbs.	325.00	$1.10	$357.50	
Electricity	kwh	1,580.00	$0.08	$126.40	
Crop insurance*	acre	1.00	$120.00	$120.00	
Baling supplies	lbs.	2,500.00	$0.003	$7.50	
Tractor/Machinery	acre	1.00	$219.31	$219.31	
Labor					
Pre-harvest	hrs.	40.00	$12.23	$489.20	
Harvest/Baling	hrs.	13.00	$12.23	$158.89	
Postharvest	hrs.	2.00	$12.23	$24.46	
Interest on op. cap.	$	$962.23	5.0%	$48.11	
Total variable costs:				$2,733.96	
3. INCOME ABOVE VARIABLE COSTS					
4. FIXED COSTS					
Tractor/Machinery	acre	1.00	$405.12	$405.12	
Bulk barn	acre	1.00	$132.58	$132.58	
Tobacco box loading sys.	acre	1.00	$38.75	$38.75	
Baler	acre	1.00	$7.50	$7.50	
H2A Overhead	acre	1.00	$206.00	$206.00	
Total fixed costs:				$789.95	
5. TOTAL COSTS				**$3,523.91**	
6. NET RETURNS TO LAND, RISK, AND MANAGEMENT					

Note: This budget is for planning purposes only and does not include land rent or general overhead cost

* Crop insurance: 75% based premium, no disaster subsidies—Pest control includes insecticides, herbicides, fungicides, and adjuvants

Prepared by: Gary Bullen, Derek Washburn—NC State Agricultural and Resource Economics Department, and Matthew Vann—NC State Tobacco Extension Specialist—for more budget details visit https://cals.ncsu.edu/are-extension/business-planning-and-operations/enterprise-budgets/

Table 1-2. Flue-cured tobacco—machine harvest—piedmont North Carolina: 2020 estimated costs per acre

	Unit	Quantity	Price or Cost/Unit	Total Per Acre	Your Farm
1. GROSS RECEIPTS					
Stalk position		Yield	Price/lb.		
Lugs	lb.	0.00	$0.00	$0.00	
Cutter	lb.	0.00	$0.00	$0.00	
Leaf	lb.	0.00	$0.00	$0.00	
Tips	lb.	0.00	$0.00	$0.00	
Total receipts:				$0.00	
2. VARIABLE COSTS					
Plants (greenhouse)	thou	6.00	$40.00	$240.00	
Multipurpose fumigation	gal	10.50	$17.13	$179.87	
Fertilizer					
6-6-18	cwt	3.50	$24.89	$87.12	
15.5-0-0	cwt	4.00	$26.23	$104.92	
Lime (prorated)	ton	0.33	$51.00	$16.83	
Pest Control*	acre	1.00	$253.19	$253.19	
Sucker Control	acre	1.00	$187.53	$187.53	
Scouting	acre	1.00	$20.00	$20.00	
Hauling	lb.	2,500.00	$0.05	$125.00	
Cover crop	acre	1.00	$25.00	$25.00	
Curing fuel	lbs.	325.00	$1.10	$357.50	
Electricity	kwh	1,580.00	$0.08	$126.40	
Crop insurance*	acre	1.00	$120.00	$120.00	
Irrigation	cycle	3.00	$13.94	$41.82	
Baling supplies	lbs.	2,500.00	$0.003	$7.50	
Tractor/Machinery	acre	1.00	$219.31	$219.31	
Labor					
Pre-harvest	hrs.	35.00	$12.23	$428.05	
Harvest/Baling	hrs.	33.00	$12.23	$403.59	
Postharvest	hrs.	2.00	$12.23	$24.46	
Interest on op. capital	$	$1,082.44	5.0%	$54.12	
Total variable costs:				$3,022.21	
3. INCOME ABOVE VARIABLE COSTS					
4. FIXED COSTS					
Tractor/Machinery	acre	1.00	$405.12	$405.12	
Bulk barn	acre	1.00	$132.58	$132.58	
Baler	acre	1.00	$7.50	$7.50	
H2A Overhead	acre	1.00	$206.00	$206.00	
Irrigation	acre	1.00	$63.50	$63.50	
Total fixed costs:				$814.70	
5. TOTAL COSTS				**$3,863.91**	
6. NET RETURNS TO LAND, RISK, AND MANAGEMENT					

Note: This budget is for planning purposes only and does not include land rent or general overhead cost

* Crop insurance: 75% based premium, no disaster subsidies—Pest control includes insecticides, herbicides, fungicides, and adjuvants

Prepared by: Gary Bullen, Derek Washburn—NC State Agricultural and Resource Economics Department, and Matthew Vann—NC State Tobacco Extension Specialist—for more budget details visit https://cals.ncsu.edu/are-extension/business-planning-and-operations/enterprise-budgets/

Table 1-3. Flue-cured tobacco—hand harvest—piedmont North Carolina: 2020 estimated costs per acre

	Unit	Quantity	Price or Cost/Unit	Total Per Acre	Your Farm
1. GROSS RECEIPTS					
Stalk position		Yield	Price/lb.		
Lugs	lb.	0.00	$0.00	$0.00	
Cutter	lb.	0.00	$0.00	$0.00	
Leaf	lb.	0.00	$0.00	$0.00	
Tips	lb.	0.00	$0.00	$0.00	
Total receipts:				$0.00	
2. VARIABLE COSTS					
Plants (greenhouse)	thou	6.00	$40.00	$240.00	
Multipurpose fumigation	gal	10.50	$17.13	$179.87	
Fertilizer					
6-6-18	cwt	3.50	$24.89	$87.12	
15.5-0-0	cwt	4.00	$26.23	$104.92	
Lime (prorated)	ton	0.33	$51.00	$16.83	
Pest Control*	acre	1.00	$253.19	$253.19	
Sucker Control	acre	1.00	$187.53	$187.53	
Scouting	acre	1.00	$20.00	$20.00	
Hauling	lbs.	2,500.00	$0.06	$156.25	
Cover crop	acre	1.00	$25.00	$25.00	
Curing fuel	lbs.	325.00	$1.10	$357.50	
Electricity	kwh	1,580.00	$0.08	$126.40	
Crop insurance*	acre	1.00	$120.00	$120.00	
Irrigation	cycle	3.00	$13.94	$41.82	
Baling supplies	lbs.	2,500.00	$0.003	$7.50	
Tractor/machinery	acre	1.00	$136.33	$136.33	
Labor					
Pre-harvest	hrs.	43.00	$12.23	$525.89	
Harvest/Baling	hrs.	67.00	$12.23	$819.41	
Postharvest	hrs.	2.00	$12.23	$24.46	
Interest on op. capital	$	$1,297.78	5.0%	$64.89	
Total variable costs:				$3,494.91	
3. INCOME ABOVE VARIABLE COSTS					
4. FIXED COSTS					
Tractor/Machinery	acre	1.00	$221.99	$221.99	
Bulk barn	acre	1.00	$132.58	$132.58	
Baler	acre	1.00	$7.50	$7.50	
H2A Overhead	acre	1.00	$206.00	$206.00	
Irrigation	acre	1.00	$63.50	$63.50	
Total fixed costs:				$631.57	
5. TOTAL COSTS				**$4,126.48**	
6. NET RETURNS TO LAND, RISK, AND MANAGEMENT					

Note: This budget is for planning purposes only and does not include land rent or general overhead cost

* Crop insurance: 75% based premium, no disaster subsidies—Pest control includes insecticides, herbicides, fungicides, and adjuvants

Prepared by: Gary Bullen, Derek Washburn—NC State Agricultural and Resource Economics Department, and Matthew Vann—NC State Tobacco Extension Specialist—for more budget details visit https://cals.ncsu.edu/are-extension/business-planning-and-operations/enterprise-budgets/

2. COMPLYING WITH NORTH CAROLINA FARM LABOR REGULATIONS

Jonathan Phillips
Senior Collegiate Lecturer, Agricultural and Resource Economics

Tobacco growers who employ workers must comply with a set of ever-changing federal and state farm labor laws, including laws pertaining to migrant labor, tax withholding, minimum wage rates, and insurance. This summary provides only a general overview of the laws that affect farm workers. For detailed information about your legal requirements as an agricultural employer, contact the appropriate agency.

IMMIGRATION

The Immigration Reform Control Act of 1986 requires employers to hire only U.S. citizens and aliens who are authorized to work in the United States. Employers must complete the I-9 form for every employee hired after 1986. The I-9 must be completed within the first three days of employment or on the first day of employment if the length of employment is less than three days. Employers must keep the I-9 either for three years or for one year after the end of employment, whichever is longer. The I-9 form is designed to verify an individual's identity and eligibility to work in the United States. An employer must accept documents that are listed on the I-9 as verification. An employer is not allowed to request additional documentation or to refuse documents that appear authentic. Employers may not refuse to hire a worker whose employment authorization expires at a later date. For forms and additional information about this requirement, contact United States Citizenship and Immigration Services, Charlotte Suboffice, 6130 Tyvola Centre Drive, Charlotte, NC 28217; www.uscis.gov.

E-Verify is mandatory for businesses that have more than 25 employees. Temporary seasonal workers employed for fewer than nine months within a consecutive 12-month period are not required to use E-Verify. These nine-month employees are not counted toward the 25 total. For example, a farm with 20 permanent employees and 50 seasonal employees who work for fewer than nine months does not have to file E-verify. E-Verify is a free Internet-based system for matching an employee's Social Security number with other I-9 information. In most cases, employers who submit an employee's information to E-Verify will receive one of two types of feedback from the system: either the information is verified, or the system returns a tentative nonconfirmation (TNC). If an employer receives a TNC for an employee, the employer should follow the directions that E-Verify provides. E-Verify is not a replacement for the I-9 form and should not be used until after an employee has completed the I-9 form. Many rules, regulations,

and requirements apply to E-Verify, and employers must understand them. For more information on North Carolina regulations, go to https://www.labor.nc.gov/workplace-rights/e-verify. You may also go to https://www.e-verify.gov/.

EMPLOYMENT DISCRIMINATION

Employers who employ 15 or more workers must consider all qualified applicants for employment. All employees, including part-time and temporary workers, are counted for this purpose. Employment includes, but is not limited to, the employment application, hiring, promotion, pay, and termination. The Civil Rights Act of 1964 prevents employment discrimination against individuals because of their membership in a protected class. Protected classes are currently defined as race, color, religion, sex, age (40 and older), disability, and national origin. For details, contact the U.S. Equal Employment Opportunity Commission, www.eeoc.gov.

TAXES

Social Security and Medicare Taxes

Agricultural employers must withhold and pay Social Security taxes on wages paid to their employees if they employ one or more agricultural workers (including parents, children age 18 or older, and spouses) and they meet either of these two requirements:

- They paid the employee at least $150 in cash wages in the year.
- They paid a total of at least $2,500 in cash wages to all employees in the year.

The 2020 Social Security rate is 6.2% for both the employee and employer portions. The maximum annual wage on which Social Security taxes must be paid will be $137,700 for 2020. Medicare tax remains at 1.45% for both employee and employer, with no wage limit. Self-employed producers must pay both portions of the Social Security and Medicare taxes.

Agricultural employers are exempt from withholding and paying Social Security taxes on wages paid to work-authorized aliens under the H2A program. For more information, contact the United States Social Security Administration or visit the agency's website: www.ssa.gov.

Income Taxes

Agricultural producers must withhold federal and state income taxes from agricultural wages if the wages are subject to Social Security tax withholdings. Each employee should complete both form W-4 (Employee's Federal Withholding Allowance Certificate) and form NC-4 (North Carolina Employee's Withholding Allowance Certificate). The employer should keep copies of both documents. Income taxes on H2A workers are handled differently. Read current legislation to determine any withholding requirements.

Unemployment Taxes

Employers must pay federal and state unemployment tax if they paid cash wages of $20,000 or more for agricultural labor during any calendar quarter in the current or preceding year or if they employed at least 10 persons in agricultural labor for some portion of the day in 20 different weeks during the preceding calendar year. H2A wages are considered for meeting the $20,000 wage test. This tax may not be deducted from the employee's salary. Federal unemployment tax is paid only on the first $7,000 of each employee's wages. The federal tax rate is 6.0%. A credit of up to 5.4% is usually granted, depending on the situation, making the effective tax rate 0.6%.

North Carolina unemployment tax is paid only on the first $25,200 of each employee's wages in 2020. The state tax rate is between 0.06% and 5.76%, depending on the credit or debt ratio. The new-business starting rate is 1.0%.

For detailed information about federal unemployment taxes, contact the Internal Revenue Service. The IRS has 10 local offices in North Carolina; to find the nearest one, visit www.irs.gov or call (800) 829-4933. For information about state income taxes, contact the North Carolina Department of Revenue, 501 North Wilmington St., Raleigh, NC 27604; (877) 252-3052; www.ncdor.gov.

You may also contact the Employment Security Commission of North Carolina, 700 Wade Ave., Raleigh, NC 27605; (919) 707-1170. The ESC has many regional offices. To find the nearest one, visit http://des.nc.gov/DES/. You may also email des.tax.customerservice@nccommerce.com.

WORKERS' COMPENSATION

Any agricultural employer who regularly employs 10 or more full-time workers must purchase workers' compensation insurance from a private insurer to cover employees should they sustain an injury on the job or contract an occupational disease. Agricultural employers who employ H2A workers must have workers' compensation insurance regardless of the total number of employees. Specific information on workers' compensation is available from the North Carolina Industrial Commission, (919) 807-2501, (800) 688-8349, or www.ic.nc.gov.

MINIMUM WAGE

Any person employed in agriculture as defined under the Fair Labor Standards Act is exempt from the North Carolina Wage and Hour Act. They are subject to the federal Fair Labor Standards Act. Generally, this applies to topics of minimum wage, overtime, and child labor.

The federal minimum wage is $7.25 per hour. Agricultural employers are exempt from paying the minimum wage if they employed fewer than five hundred man-days of agricultural labor in any quarter of the preceding year. A man-day is defined as any day in which one employee is employed for one hour or more. A farm will generally fall under the man-day provision if six or fewer full-time employees are hired.

Travel time to a job site is considered as hours worked, and the employee must be paid for those hours if his or her job would be affected in any adverse way by not using company transportation. For example, if one employee receives instructions during the trip, loads equipment on vehicles, or is required to use company transportation, the trip time must be considered as hours worked for all employees using that transportation. For additional information, contact the U.S. Department of Labor, Employment Standards Administration, Wage and Hour Division, (866) 4-US-WAGE, or visit the division's web site: www.dol.gov/WHD.

Overtime

Agricultural employers are still exempt from paying overtime (1.5 times the regular hourly wage rate for any hours worked in excess of 40 in one week). Christmas tree production is agriculture and is thus exempt. (See U.S. Department of Labor v. NC Growers Association appeal case.)

If an employee performs a mix of agricultural and nonagricultural work within the same week, such as working in the field and selling products at a roadside stand, then the entire week is considered nonexempt. For these nonexempt employees, overtime is calculated per work week, not per pay period. For example, assume that a nonexempt employee is paid every two weeks and works for 46 hours one week and 34 the next in the same pay period. In that scenario, the employer owes the employee 74 hours of standard pay and 6 hours of overtime. For more information, contact the U.S. Department of Labor's Wage and Hour Division at the phone number or web address noted above.

Executive, administrative, and professional employees are exempt from overtime if salaried greater than $684/week or $35,568/year. The U.S. Department of Labor issued this wage rule in September 2019. The rule is effective January 1, 2020.

CHILD LABOR PROVISIONS

The minimum age for working in agriculture is 16 if the job is considered hazardous or is performed during school hours. Minors of age 14 or 15 may work in agriculture if the job is not during school hours and not hazardous. An exception is made for operating hazardous equipment if the minor has completed the 4-H training programs for tractor and machine operation through the Cooperative Extension Service of a land-grant university and received the appropriate certification. Minors of age 12 or 13 may be employed with their parents' written consent on a farm where their parents are also employed. Minors of any age may be employed at any time in any occupation on a farm owned and operated by their parents.

North Carolina prohibits any child who is younger than age 16 from riding in an open bed or cargo area of a vehicle that is without permanent overhead restraining construction. Exceptions may be made under certain specific circumstances, such as when an adult is present in the bed or cargo area of the vehicle, and the adult is supervising the child. For detailed information about vehicle safety laws, contact the Governor's Highway Safety Program, North Carolina Department of Transportation, (919) 814-3650, or visit the program's website: http://www.ncdot.gov/.

JOINT EMPLOYMENT

The term joint employment denotes a situation in which an individual is considered an employee of two or more persons. Joint employment situations often arise with individuals employed by farm labor contractors and farm owners. If a joint employment relationship exists and a crew leader is unable to pay wages to workers or taxes to the government, then the farm owner could be liable. Joint employment is determined by the following factors:

- Nature and degree of control over workers
- Degree of supervision
- Power to determine pay rates
- Right to hire, fire, or modify employment conditions
- Preparation of payroll and payment of wages

VEHICLE INSURANCE

Agricultural employers, in general, are subject to the Migrant and Seasonal Agricultural Worker Protection Act (MSPA) if they employed five hundred man-days of labor during any calendar quarter. The MSPA requires $100,000 worth of vehicle insurance for every seat in the vehicle. For example, a 15-passenger van must have $1.5 million of insurance. The maximum requirement, including buses, is $5 million per vehicle. For additional information about vehicle insurance, contact the U.S. Department of Labor, (866) 4-USA-DOL, or visit the department's MSPA compliance site: https://www.dol.gov/whd/mspa/.

FARM LABOR CONTRACTORS

A farm labor contractor (FLC) is a person who recruits, solicits, hires, employs, furnishes, transports, or houses agricultural labor. Commonly known as a crew leader, such a contractor works mostly with migrant or seasonal workers. FLCs must have a federal license to operate in North Carolina. A farm labor contractor must obtain the appropriate authorization certificates to house and transport laborers and drive transportation. To inquire about the validity of a certificate, call 1-866-4-US-WAGE (1-866-487-9243).

An employer must be on the preauthorization H2A application to use H2A workers provided by a crew leader (H2ALC workers). Under joint employment laws, if a farm labor contractor performs a function he or she is not certified in, the farm owner could be held liable.

A farm labor contractor (FLC) is a person who recruits, solicits, hires, employs, furnishes, transports, or houses agricultural labor. Commonly known as a crew leader, such a contractor works mostly with migrant or seasonal workers. FLCs must have a federal license to operate in NC. A farm labor contractor must obtain the appropriate authorization certificates to house and transport laborers and drive transportation. To inquire about the validity of a certificate call 1-866-4-US-WAGE (1-866-487-9243).

An employer must be on the preauthorization H2A application to use H2A workers provided by a crew leader (H2ALC workers). Under joint employment laws, if a farm labor contractor performs a function he or she is not certified in, the farm owner could be held liable.

North Carolina Department of Commerce, Division of Workforce Solutions staff can assist in the application process for farm labor contractor licensing and adding authorizations. To find an office in your area, call the Agricultural Services Unit at (919) 814-0544 or visit www.NCWorks.gov.

MIGRANT HOUSING

If an agricultural producer provides housing to one or more migrant or seasonal workers, the workers are covered under the Migrant Housing Act. The producer must register the housing and notify the North Carolina Department of Labor 45 days before any workers arrive. The housing must meet certain standards, which can be obtained from the North Carolina Department of Labor's Bureau of Agricultural Safety and Migrant Housing. To register migrant housing, call (919) 707-7820 or obtain the registration form online, https://www.labor.nc.gov/safety-and-health/agricultural-safety-and-health.

FIELD SANITATION

Agricultural employers who employ 11 or more workers on any given day or provide housing for one or more workers must provide the following:

- One field toilet per 20 workers or fraction thereof
- Hand-washing facilities
- Suitable cool, potable drinking water with individual cups

POSTER REQUIREMENT

Some North Carolina employers are required to place government posters in conspicuous places that explain employees' rights. If an employee is illiterate, then the poster information must be read to the employee in a manner they can comprehend. These posters are available free of charge from the website below. There is no need to buy these free posters from companies who are trying to sell them. Not all operations will be covered by the same statutes, so the requirements vary by individual business. Visit the following website to determine which poster you are required to display: https://www.labor.nc.gov/safety-and-health/publications/state-and-federal-workplace-poster-requirements.

NEW HIRE REPORTING

North Carolina employers are required to report to state government the names, addresses, Social Security numbers, dates of birth, and dates of employment of all new employees. Employers are also required to report their names, addresses, and state employer identification

numbers. This must be done within 20 days of a new hire's initial employment. An employer can complete a special form or make a copy of the new employee's W-4, plus the additional information, and send it to North Carolina State Directory of New Hires, P.O. Box 90369, East Point, GA 30364-0369. An employer may also submit the information electronically at https://newhire-reporting.com/nc-newhire/Default.aspx. For more information, call (888) 514-4568.

The North Carolina Department of Labor administers the state's labor laws. For detailed information about wages and overtime, child labor laws, migrant labor, work conditions, and other labor laws that affect agricultural workers, contact the department: (800) NCLABOR or www. nclabor.com.

NEW LAWS AND REGULATIONS

Additions to the 2020 handbook beyond typical figure updates: Changes in labor law are being proposed at the time of this writing (October 2019). All producers are encouraged to stay informed about changes that may occur before this guide is published again.

3. SELECTING A VARIETY

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According to a recent survey, NC 196 was the most popular variety of flue-cured tobacco planted in North Carolina during 2019. NC 196 was grown on 48 percent of the tobacco acres in the state. Other popular varieties were K 326 (12 percent), CC 143 (11 percent), GF 318 (5 percent) K 346 and GL 395 (4 percent each), and CC 1063, PVH 2310, and NC 71 (3 percent each). Figure 3-1 shows the most popular varieties planted since 2013. To select the right variety for your fields, consider the information produced during variety testing at a research station in your area.

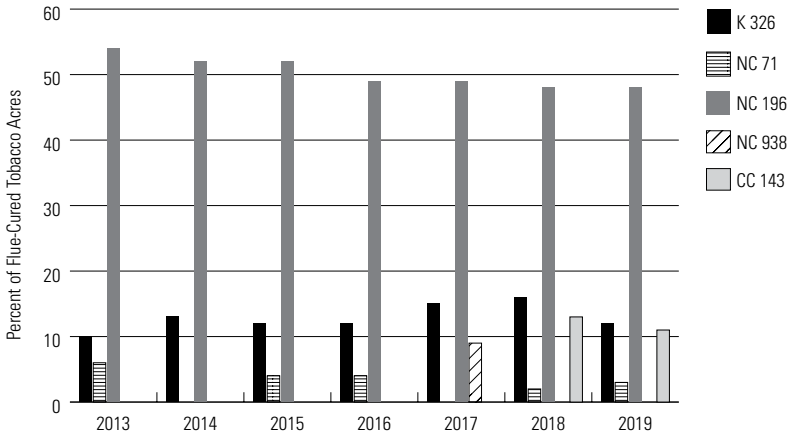

Figure 3-1. N.C. Cooperative Extension agent estimates of plantings of several popular varieties, 2013-2019

VARIETY TESTING

The variety testing program conducted through the Agricultural Research Service at North Carolina State University evaluates breeding lines through the Regional Minimum Standards Program and commercial varieties through the North Carolina Official Variety Test (OVT).

The Regional Minimum Standards Program is designed to ensure that varieties planted by growers are acceptable to the tobacco industry. Once a breeding line is genetically stable, it can be entered into the Regional Small Plot Test (RSPT) conducted cooperatively by university researchers in Georgia, North Carolina, and Virginia. Breeding lines that pass the minimum standards for chemical quality in the RSPT can be entered in the Regional Farm Test (RFT). In the RFT, researchers plant breeding lines at nine locations. Four of the RFT locations are in North Carolina. If a breeding line passes the RFT, which includes a smoke test, it is eligible for release as a commercial variety.

The OVT is designed to assist growers with variety selection, and it is conducted at these research stations:

- Lower Coastal Plain Research Station—Kinston
- Upper Coastal Plain Research Station—Rocky Mount
- Oxford Tobacco Research Station—Oxford

Note that the OVT is conducted in fields with little, if any, soilborne disease, such as black shank and Granville wilt. Therefore, the yield and quality differences among varieties will differ depending on disease pressure. For example, K 326 is one of the highest-yielding varieties in the OVT, but its yield would be much lower in fields with high pressure from black shank and Granville wilt.

Because 2018 was an unusual production year with many adverse weather events, data from the 2018 OVT are not representative of expected variety performance and are therefore not reported in the 2020 production guide.

VARIETY SELECTION

The research findings reported in this guide can help you select the right variety for your fields.

Consider disease resistance first. Table 8-3 in chapter 8, "Managing Diseases," provides a list of popular varieties and their ratings for resistance to black shank and Granville wilt, the two diseases that pose the most serious threats to flue-cured crops in North Carolina. (Table 8-3 also lists varieties' resistance to tobacco mosaic virus.) Determine the level of disease resistance that you need based on field history, length of rotation, and crops grown in rotation with tobacco. After you determine the necessary level of disease resistance, consider agronomic characteristics, such as yield, quality, and holding ability. Multiyear data, such as the three-year average shown in tables 3-1 and 3-7 and the two-year average shown in tables 3-2 and 3-8, are better than single-year data.

Averaging information across years removes much of the environmental effect and provides a stable picture of a variety's performance over time. However, single-year data (tables 3-3 and

3-9) and individual location data (tables 3-4 through 3-6) are helpful when you wish to see data collected from a specific growing region and under certain climatic conditions.

Consider holding ability—the ability of a variety to hold its ripeness during the harvest period. Figures 3-2 through 3-7 in this chapter compare the value of the last priming for several popular varieties based on harvest schedule.

Table 3-1. Performance of commercial varieties in the North Carolina Official Variety Test, three year average, 2016-2017 and 2019

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. To Alk.
CC 1063	2619	4391	167.64	81	67	18.6	39	2.10	14.51	2.90	5.01
CC 13	2759	4549	164.90	80	67	19.3	40	2.07	15.77	2.59	6.08
CC 143	2976	4954	166.45	80	68	19.7	41	2.08	16.99	2.62	6.48
CC 27	2779	4672	168.13	81	67	19.2	39	2.02	16.57	2.60	6.38
CC 33	2645	4479	169.34	82	68	19.8	39	1.96	15.20	2.34	6.50
CC 35	2977	4847	162.82	79	70	19.4	44	2.29	16.58	2.64	6.29
CC 37	2807	4563	162.57	79	68	19.2	40	2.10	17.10	2.46	6.94
CC 67	2715	4527	166.71	80	66	18.7	40	2.12	16.19	2.76	5.86
CC 700	2782	4641	166.83	81	65	18.5	38	2.04	15.79	2.75	5.75
GF 318	2841	4734	166.64	80	67	19.1	40	2.11	16.62	2.76	6.03
GL 26H	2909	4828	166.48	81	68	19.5	40	2.06	17.11	2.65	6.51
GL 395	2618	4212	160.87	78	66	18.9	40	2.12	14.69	2.97	4.95
K 326	2950	4828	163.66	80	67	19.0	38	2.01	17.82	2.54	7.02
K 346	2649	4226	159.54	79	66	18.6	38	2.05	15.24	2.81	5.43
NC 196	2980	4986	167.32	81	67	19.4	41	2.10	16.15	2.60	6.20
NC 299	2838	4771	168.13	81	68	19.3	39	2.03	16.87	2.67	6.32
NC 606	2705	4378	161.87	79	66	18.4	41	2.21	16.36	2.73	5.99
NC 925	2875	4362	151.69	75	67	19.0	38	2.01	17.21	2.60	6.63
NC 938	2818	4576	162.36	80	67	18.9	41	2.17	13.55	2.71	4.99
Test Average	2802	4594	164.42	80	67	19.1	40	2.09	16.12	2.67	6.02

Table 3-2. Performance of commercial varieties in the North Carolina Official Variety Test, two year average, 2017 and 2019

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. To Alk.
CC 1063	2505	4172	166.58	81	69	19.0	38	2.00	14.81	2.97	4.98
CC 13	2764	4527	163.77	79	67	19.5	39	2.02	16.49	2.67	6.17
CC 143	2891	4747	164.18	80	68	20.3	40	1.99	17.29	2.64	6.56
CC 144	2737	4544	166.04	80	68	19.7	41	2.08	17.39	2.47	7.05
CC 145	2817	4699	166.84	81	69	19.4	42	2.17	17.54	2.55	6.87
CC 27	2824	4740	167.82	81	67	19.6	38	1.95	16.78	2.59	6.47
CC 33	2612	4389	168.06	83	68	20.2	38	1.88	15.16	2.35	6.46
CC 35	2880	4561	158.37	76	72	19.6	45	2.28	17.17	2.69	6.37
CC 37	2819	4605	163.34	80	69	19.8	40	2.04	17.97	2.44	7.38
CC 67	2744	4554	165.98	80	67	19.0	39	2.08	16.09	2.81	5.72
CC 700	2830	4678	165.30	80	66	18.8	37	1.99	15.95	2.78	5.74
GF 318	2839	4797	169.00	81	68	19.8	40	2.00	16.58	2.78	5.96
GL 26H	2913	4563	156.63	78	69	19.5	39	2.00	18.75	2.44	7.70
GL 365	2908	5034	173.15	83	70	21.1	41	1.92	17.10	2.68	6.39
GL 395	2660	4238	159.32	77	66	19.3	40	2.06	15.12	3.08	4.92
K 326	2954	4820	163.19	80	68	19.5	38	1.93	18.05	2.56	7.04
K 346	2688	4285	159.41	78	66	18.8	38	2.01	15.79	2.90	5.45
NC 1226	2913	4760	163.37	79	69	19.7	39	1.99	16.53	2.59	6.38
NC 196	2809	4703	167.45	80	68	19.5	40	2.05	16.36	2.63	6.21
NC 297	2955	4784	161.93	79	69	19.0	38	1.99	17.88	2.84	6.29
NC 299	2841	4810	169.29	82	69	19.6	39	1.99	17.35	2.58	6.73
NC 606	2698	4294	159.16	78	68	19.1	41	2.12	16.80	2.81	5.99

Table 3-2. *(continued)*

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. To Alk.
NC 925	2882	4452	154.49	76	68	19.3	38	1.96	17.79	2.54	7.00
NC 938	2682	4341	161.88	80	68	19.3	40	2.09	13.25	2.77	4.79
Test Average	2812	4593	163.30	79	68	19.5	39	2.02	16.65	2.68	6.21

Table 3-3. Performance of commercial varieties in the North Carolina Official Variety Test, combined over three locations, 2019

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. To Alk.
CC 1063	2544	4310	169.42	82	67	19.4	39	2.03	15.69	2.67	5.87
CC 13	2588	4191	161.92	79	65	20.5	40	1.97	16.74	2.45	6.83
CC 143	2735	4239	155.01	77	67	20.7	42	2.03	18.43	2.39	7.71
CC 144	2547	4364	171.34	83	66	20.0	42	2.08	17.16	2.29	7.49
CC 145	2646	4376	165.38	81	68	19.4	43	2.21	17.62	2.27	7.75
CC 27	2696	4505	167.08	81	66	20.3	40	1.95	17.28	2.38	7.26
CC 33	2445	4265	174.42	84	66	21.0	38	1.82	14.71	2.34	6.29
CC 35	2781	4520	162.53	77	70	19.4	45	2.33	16.83	2.60	6.47
CC 37	2678	4468	166.89	81	68	20.4	41	2.01	18.93	2.19	8.64
CC 67	2636	4444	168.57	82	66	19.5	41	2.08	16.96	2.59	6.54
CC 700	2664	4361	163.71	80	65	19.5	38	1.97	17.23	2.54	6.78
GF 318	2670	4490	168.13	82	66	20.2	40	1.98	17.31	2.55	6.78
GL 26H	2743	4324	157.64	77	68	20.5	41	2.03	18.42	2.27	8.11
GL 365	2712	4677	172.47	84	68	22.2	41	1.80	16.85	2.46	6.85
GL 395	2563	4334	169.11	82	66	19.6	40	2.03	16.07	2.67	6.02
K 326	2825	4557	161.30	79	67	20.1	39	1.96	18.86	2.35	8.02
K 346	2398	3921	163.50	80	66	19.3	38	1.99	15.64	2.71	5.77
NC 1226	2651	4432	167.17	81	67	20.3	39	1.95	16.32	2.46	6.63
NC 196	2463	4034	163.75	80	66	20.0	41	2.05	17.03	2.41	7.06
NC 1960	2968	4773	160.81	80	68	21.2	42	1.95	17.38	2.27	7.65
NC 297	2700	4522	167.47	81	67	19.8	38	1.95	18.05	2.59	6.97
NC 299	2740	4609	168.22	82	67	20.4	41	2.00	18.24	2.28	8.00

Table 3-3. *(continued)*

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. To Alk.
NC 606	2514	3998	159.01	78	66	19.8	41	2.08	17.45	2.59	6.73
NC 925	2755	4462	161.98	79	66	20.0	39	1.91	18.18	2.31	7.87
NC 938	2486	4189	168.48	82	67	19.7	41	2.06	15.05	2.49	6.04
NC 980	2493	3918	157.14	77	66	19.6	39	2.05	15.22	2.32	6.56
NC 986	2914	4686	160.82	79	66	20.4	41	2.01	17.78	2.30	7.73
NC 987	3020	4998	165.48	80	66	19.1	40	2.11	19.38	2.18	8.89
NC 989	3229	5049	156.35	77	66	19.7	38	1.98	17.98	2.39	7.52
PVH 1610	2697	4562	169.16	82	66	20.6	40	1.98	16.20	2.63	6.16
PVH 2343	2794	4916	175.97	84	68	20.4	42	2.08	17.40	2.24	7.76
PVH 2408	2361	4031	170.70	82	66	20.1	40	2.05	17.63	2.17	8.12
Test Average	2677	4426	165.34	80	67	20.1	40	2.01	17.19	2.42	7.11

Table 3-4. Performance of commercial varieties in the North Carolina Official Variety Test, Oxford, NC, 2019

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. To Alk.
CC 1063	2427	4097	168.78	83	66	19.6	39	1.97	12.60	2.97	4.25
CC 13	2411	3950	163.78	81	65	19.7	35	1.79	13.67	2.87	4.77
CC 143	2302	3737	162.30	80	69	19.5	38	1.96	15.43	2.73	5.65
CC 144	2373	4016	169.20	83	66	19.2	39	2.03	13.73	2.50	5.49
CC 145	2178	3610	165.73	81	67	18.2	40	2.22	14.37	2.83	5.07
CC 27	2581	4337	168.03	83	66	19.7	35	1.77	13.50	3.07	4.40
CC 33	2136	3629	169.90	83	64	19.6	34	1.74	11.27	2.93	3.84
CC 35	2433	4142	170.25	82	73	19.9	45	2.24	13.00	3.17	4.11
CC 37	2235	3746	167.63	82	71	20.2	38	1.90	16.10	2.43	6.62
CC 67	2299	3726	162.10	79	66	19.9	35	1.76	13.57	3.10	4.38
CC 700	2227	3750	168.40	83	67	19.7	35	1.80	13.37	2.87	4.66
GF 318	2336	3941	168.70	83	67	18.3	36	1.95	12.93	3.13	4.13
GL 26H	2556	4356	170.43	83	68	20.9	41	1.94	16.47	2.67	6.17
GL 365	2504	4047	161.60	81	67	22.6	37	1.64	14.23	2.90	4.91
GL 395	2322	3928	169.20	82	64	18.8	35	1.86	14.20	3.00	4.73
K 326	2405	4017	167.03	82	67	19.4	36	1.87	17.00	2.60	6.54
K 346	2487	3990	160.43	80	65	19.3	36	1.87	13.70	3.13	4.37
NC 1226	2514	4068	161.83	80	67	20.0	37	1.84	11.70	3.03	3.86
NC 196	1952	3256	166.85	82	68	19.3	37	1.92	15.23	2.93	5.19
NC 1960	2547	4293	168.53	83	66	20.1	37	1.82	15.23	2.63	5.78
NC 297	2350	3952	168.13	83	67	19.3	36	1.86	15.83	2.97	5.34
NC 299	2341	3842	164.10	81	68	20.1	37	1.86	14.60	2.73	5.34
NC 606	2134	3634	170.30	83	66	18.6	38	2.06	14.80	3.10	4.77

Table 3-4. *(continued)*

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. To Alk.
NC 925	2374	3891	163.92	81	68	20.7	38	1.85	16.60	2.43	6.82
NC 938	2211	3566	161.30	80	68	19.2	38	1.99	10.97	3.07	3.58
NC 980	2970	4759	160.25	80	66	19.5	35	1.80	12.73	2.60	4.90
NC 986	2603	4287	164.68	81	66	19.9	39	1.94	14.13	3.23	4.37
NC 987	2933	4779	162.93	80	64	18.1	36	2.00	15.73	2.50	6.29
NC 989	2692	4418	164.10	81	65	19.0	36	1.88	14.30	3.03	4.71
PVH 1610	2482	4193	168.98	82	65	20.0	37	1.85	13.30	3.27	4.07
PVH 2343	2552	4387	171.93	84	68	20.1	39	1.96	13.03	2.83	4.60
PVH 2408	2124	3592	169.14	83	66	19.1	38	1.97	15.30	2.60	5.88
Test Average	2406	4000	166.26	82	67	19.6	37	1.90	14.14	2.87	4.93

Table 3-5. Performance of commercial varieties in the North Carolina Official Variety Test, Kinston, NC, 2019

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. To Alk.
CC 1063	3204	5830	182.00	86	69	20.8	43	2.10	17.63	2.17	8.14
CC 13	2961	4545	153.50	75	67	21.4	46	2.13	16.97	2.23	7.60
CC 143	3351	4706	140.43	70	68	21.8	46	2.10	17.73	2.20	8.06
CC 144	3208	5847	182.27	86	67	21.9	47	2.15	19.40	2.00	9.70
CC 145	3333	5383	161.48	78	70	21.2	47	2.20	19.97	1.80	11.09
CC 27	3089	5535	179.18	85	69	21.5	45	2.07	16.83	2.07	8.15
CC 33	2998	5394	179.93	86	69	23.4	39	1.66	15.77	1.80	8.76
CC 35	3388	5458	161.08	78	69	21.1	49	2.35	16.63	2.13	7.80
CC 37	3276	5270	160.88	78	71	21.9	43	1.99	18.47	2.07	8.94
CC 67	3148	5655	179.65	85	68	20.4	45	2.22	17.67	2.23	7.91
CC 700	3347	5448	162.78	79	66	20.8	42	2.02	18.37	2.43	7.55
GF 318	3143	5513	175.43	83	67	23.0	46	1.99	20.43	2.03	10.05
GL 26H	3471	4861	140.05	70	72	20.9	45	2.14	18.97	2.00	9.48
GL 365	3441	6320	183.65	87	70	23.6	44	1.88	16.83	2.17	7.77
GL 395	3209	5523	172.14	82	69	21.5	46	2.15	16.27	2.27	7.18
K 326	3685	6312	171.28	83	68	21.4	43	2.01	20.07	2.23	8.99
K 346	2936	5318	181.14	80	68	21.0	44	2.09	17.27	2.23	7.73
NC 1226	3254	6010	184.70	87	70	21.8	43	1.97	17.80	2.07	8.61
NC 196	3186	5522	173.30	83	67	21.8	47	2.16	17.67	1.90	9.30
NC 1960	3830	6384	166.70	80	70	22.8	46	2.03	18.47	1.93	9.55
NC 297	3252	5623	172.90	83	71	21.1	42	1.99	17.83	2.40	7.43
NC 299	3612	6538	181.00	85	69	21.4	45	2.08	19.63	2.03	9.66

Table 3-5. *(continued)*

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. To Alk.
NC 606	3299	4887	148.15	73	67	22.0	48	2.21	19.23	2.17	8.88
NC 925	3114	5335	171.30	82	68	21.9	41	1.89	18.13	2.20	8.24
NC 938	3085	5597	181.43	86	68	20.8	46	2.19	18.40	2.10	8.76
NC 980	3179	5670	178.33	84	67	20.7	45	2.18	18.57	2.00	9.28
NC 986	3527	6057	171.73	83	69	21.4	44	2.08	19.30	1.83	10.53
NC 987	3456	6210	179.68	84	72	21.5	45	2.09	20.10	1.93	10.40
NC 989	4010	6447	160.75	78	70	21.7	42	1.95	19.93	2.13	9.34
PVH 1610	3370	5603	166.28	80	68	21.3	44	2.06	16.33	2.30	7.10
PVH 2343	3452	6300	182.50	86	71	22.4	46	2.04	19.50	1.73	11.25
PVH 2408	2899	5096	175.80	83	69	22.4	45	2.03	18.37	1.80	10.20
Test Average	3303	5638	170.67	81	69	22	45	2.07	18.27	2.08	8.78

Table 3-6. Performance of commercial varieties in the North Carolina Official Variety Test, Rocky Mount, NC, 2019

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. To Alk.
CC 1063	2155	3394	157.50	78	65	18.0	36	2.02	16.98	2.80	6.06
CC 13	2392	4030	168.47	81	64	20.3	40	1.97	19.43	2.28	8.54
CC 143	2551	4141	162.30	79	66	20.9	41	1.96	19.92	2.00	9.96
CC 144	2288	3731	163.10	79	64	19.0	39	2.04	18.48	2.10	8.80
CC 145	2448	4166	170.18	83	66	19.1	42	2.19	18.42	2.17	8.50
CC 27	2419	3727	154.05	76	64	19.7	39	2.00	21.10	2.08	10.17
CC 33	2203	3820	173.43	84	65	20.1	38	1.87	17.03	2.28	7.48
CC 35	2533	3711	146.47	71	69	17.4	42	2.42	20.48	2.50	8.19
CC 37	2522	4351	172.50	83	63	19.1	41	2.15	21.98	2.08	10.59
CC 67	2463	4038	163.95	81	63	18.3	41	2.24	19.50	2.45	7.96
CC 700	2418	3867	159.95	78	62	18.1	38	2.08	19.83	2.35	8.44
GF 318	2532	4058	160.28	79	65	19.1	39	2.04	18.68	2.48	7.55
GL 26H	2357	3829	162.45	78	65	19.0	37	1.96	19.93	2.15	9.27
GL 365	2332	4015	172.18	83	67	21.7	40	1.85	19.35	2.33	8.32
GL 395	2158	3591	166.40	81	64	18.6	39	2.07	17.80	2.70	6.59
K 326	2385	3472	145.60	72	67	18.5	38	2.06	19.75	2.23	8.88
K 346	2024	3042	150.30	75	64	17.7	35	1.99	16.25	2.73	5.96
NC 1226	2379	3688	155.00	76	65	19.2	39	2.02	19.25	2.30	8.37
NC 196	2252	3642	161.72	78	64	18.8	39	2.06	18.33	2.13	8.59
NC 1960	2472	3966	160.42	78	68	20.6	41	1.98	18.60	2.23	8.36
NC 297	2498	4031	161.37	79	63	19.0	37	1.97	20.40	2.43	8.41
NC 299	2266	3616	159.58	79	64	19.8	40	2.01	20.43	2.10	9.73
NC 606	1955	3122	159.68	78	65	18.9	35	1.85	16.81	2.55	6.59

Table 3-6. *(continued)*

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. To Alk.
NC 925	2552	3855	151.10	75	62	18.9	37	1.96	19.88	2.28	8.74
NC 938	2163	3520	162.72	80	66	19.0	38	2.01	16.00	2.33	6.88
NC 980	2294	3048	132.85	68	66	18.5	37	2.02	14.88	2.33	6.40
NC 986	2861	4180	146.08	73	65	20.0	40	2.00	19.88	1.93	10.32
NC 987	2825	4346	153.85	75	64	17.7	39	2.23	20.56	1.90	10.81
NC 989	3191	4254	133.32	67	64	18.4	39	2.12	19.75	2.08	9.52
PVH 1610	2270	3910	172.22	83	66	19.9	40	1.99	18.83	2.38	7.93
PVH 2343	2740	4754	173.50	84	64	18.6	42	2.27	19.60	2.15	9.12
PVH 2408	2061	3604	174.85	85	64	18.8	38	2.01	19.28	2.10	9.18
Test Average	2405	3839	160	78	65	19	39	2.04	18.98	2.28	8.34

Table 3-7. Performance of commercial varieties in the North Carolina Official Variety Test, three-year average, 2015-2017

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. to Alk.
CC 1063	2864	4918	170.83	82	70	17.5	39	2.26	14.26	3.00	5.13
CC 13	2989	5127	170.44	82	69	18.0	39	2.18	14.42	2.78	5.60
CC 143	3126	5453	174.06	83	71	18.9	41	2.18	16.57	2.73	6.34
CC 27	2965	5132	172.53	83	69	18.1	38	2.11	15.62	2.76	5.92
CC 33	2879	4866	169.39	81	71	18.7	40	2.12	15.33	2.55	6.58
CC 35	3181	5200	164.38	79	73	18.7	44	2.37	16.83	2.78	6.41
CC 37	2931	4735	160.04	77	69	18.5	40	2.17	15.55	2.73	6.01
CC 67	2729	4584	166.75	80	69	17.8	39	2.18	15.27	2.89	5.51
CC 700	2959	5139	172.93	83	66	17.7	37	2.10	14.46	3.01	5.11
GF 318	3098	5161	165.92	80	69	18.5	40	2.19	15.49	2.90	5.66
GL 309	3093	5228	168.41	81	70	18.5	40	2.18	14.89	3.02	5.28
GL 394	3241	5286	162.07	78	72	19.6	41	2.09	16.74	2.39	7.55
GL 395	2781	4627	165.54	80	68	18.0	41	2.28	13.73	3.20	4.57
GL 398	3132	5301	170.35	82	73	19.5	41	2.11	17.13	2.93	6.21
K 326	3094	5256	169.04	81	69	17.9	37	2.09	16.53	2.78	6.22
K 346	2818	4557	162.98	78	68	18.0	39	2.18	14.15	2.91	5.18
K 730	2880	4757	165.67	80	68	18.0	38	2.12	16.26	2.82	6.01
NC 196	3293	5644	171.41	82	70	19.0	41	2.17	15.49	2.73	5.96
NC 299	2997	5053	168.81	81	71	18.6	38	2.07	15.64	2.92	5.53
NC 606	2837	4715	167.07	80	69	17.6	40	2.29	16.02	2.88	5.88

Table 3-7. *(continued)*

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. to Alk.
NC 71	3069	5075	166.43	80	69	17.9	37	2.08	15.82	3.03	5.49
NC 925	3133	4928	157.68	76	70	18.3	39	2.11	16.10	2.81	6.07
NC 938	3109	5061	162.07	78	69	18.2	41	2.24	13.58	2.81	5.05
PVH 1452	2813	4835	170.63	82	68	18.7	40	2.12	14.51	2.96	5.26
PVH 1600	2928	4834	166.65	80	70	18.8	40	2.12	14.23	2.93	5.11
PVH 1920	3007	4921	163.64	79	69	18.7	39	2.11	14.53	2.89	5.24
PVH 2110	2948	5013	169.15	81	73	19.5	41	2.09	14.68	2.60	5.98
PVH 2254	3093	5050	163.69	79	70	18.9	42	2.21	15.12	2.73	5.92
PVH 2275	2691	4473	165.33	80	70	18.2	40	2.19	14.35	2.88	5.43
PVH 2310	2803	4902	174.39	84	68	18.5	40	2.18	13.74	2.71	5.23
Test Average	2983	4994	167.28	80	70	18.4	40	2.16	15.23	2.84	5.71

Table 3-8. Performance of commercial varieties in the North Carolina Official Variety Test, two-year average, 2016-2017

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. to Alk.
CC 1063	2823	4731	166.84	81	68	17.6	39	2.24	13.66	3.05	4.82
CC 13	2979	5037	167.63	81	68	18.1	40	2.18	14.51	2.66	5.88
CC 143	3166	5523	174.37	83	68	18.9	41	2.17	16.74	2.74	6.32
CC 27	2908	4929	169.08	81	67	18.2	38	2.12	15.49	2.73	5.99
CC 33	2836	4685	166.15	80	69	18.9	40	2.14	15.33	2.43	6.92
CC 35	3170	4998	159.21	77	70	18.9	44	2.35	16.28	2.64	6.59
CC 37	2902	4565	156.60	76	67	18.3	40	2.21	15.80	2.69	6.28
CC 67	2786	4587	162.80	78	67	18.0	39	2.16	15.71	2.88	5.73
CC 700	2952	5030	169.40	82	64	17.6	38	2.14	14.75	2.88	5.36
GL 26H	3261	5300	162.53	79	67	18.0	39	2.18	17.75	2.62	6.85
GF 318	3018	5022	165.99	80	68	18.4	40	2.22	15.91	2.89	5.74
GL 309	3006	5013	166.48	80	68	18.6	41	2.19	14.87	2.99	5.22
GL 394	3151	4880	154.73	75	69	19.3	40	2.09	16.92	2.36	7.82
GL 395	2720	4341	159.27	77	66	17.9	41	2.30	13.71	3.15	4.64
GL 398	3170	5222	166.06	80	70	19.5	41	2.12	16.97	2.79	6.47
GL 976	3128	5170	165.42	80	68	17.7	39	2.21	17.34	2.73	6.76
K 326	3112	5183	165.75	80	67	18.0	38	2.10	17.00	2.68	6.57
K 346	2819	4372	156.62	76	66	17.9	39	2.17	14.54	2.87	5.44
K 730	2865	4561	160.16	78	65	17.9	38	2.15	16.08	2.78	5.94
NC 196	3278	5513	168.15	81	68	18.8	41	2.17	15.67	2.71	6.08
NC 299	2976	4899	165.12	79	69	18.3	38	2.09	15.94	2.92	5.64
NC 606	2864	4641	163.20	79	67	17.4	40	2.30	15.77	2.81	5.99

Table 3-8. *(continued)*

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. to Alk.
NC 71	3097	5060	164.28	80	67	18.0	38	2.11	15.77	2.96	5.58
NC 72	3139	4882	157.33	77	67	17.8	40	2.23	15.62	2.71	5.94
NC 925	3072	4638	151.78	74	68	18.3	38	2.09	16.45	2.78	6.18
NC 938	3090	4839	155.87	76	68	18.3	41	2.25	12.77	2.85	4.67
NC 970	3478	5989	171.45	82	69	19.4	41	2.10	16.18	2.60	6.53
NC 971	3138	5402	172.08	83	67	18.7	40	2.14	16.08	2.52	6.55
NC 972	3263	5677	173.70	83	69	17.7	38	2.18	15.48	2.70	6.17
PVH 1452	2821	4769	167.48	81	66	18.7	39	2.10	14.85	2.88	5.58
PVH 1600	2921	4640	161.15	78	69	19.0	40	2.13	14.27	2.97	4.98
PVH 1920	3042	4862	159.35	77	67	18.6	39	2.13	14.51	2.87	5.20
PVH 2110	2859	4797	166.77	80	72	19.9	41	2.08	15.10	2.46	6.45
PVH 2254	3119	4936	158.96	77	67	19.0	42	2.20	15.40	2.64	6.15
PVH 2275	2677	4364	161.91	78	68	18.2	40	2.20	14.66	2.79	5.73
PVH 2310	2788	4823	172.30	83	66	18.5	40	2.19	13.04	2.65	5.06
PVH 2360	3002	4764	158.31	76	67	18.7	42	2.25	15.96	3.36	4.93
Test Average	3011	4936	163.90	79	68	18.4	40	2.17	15.48	2.78	5.91

Table 3-9. Performance of commercial varieties in the North Carolina Official Variety Test, combined over three locations, 2017

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. to Alk.
CC 1063	2749	4517	162.40	79	73	18.2	37	2.02	13.76	3.31	4.40
CC 13	3058	5105	165.83	80	70	18.1	38	2.09	14.98	2.93	5.35
CC 143	3159	5566	175.99	83	70	19.1	39	2.03	16.84	2.91	5.96
CC 144	2909	4789	164.05	79	71	19.2	40	2.09	17.49	2.69	6.81
CC 145	3078	5181	168.09	81	70	19.2	41	2.12	17.47	2.83	6.23
CC 27	3034	5091	168.41	81	69	18.6	36	1.96	16.01	2.83	5.74
CC 33	2892	4567	159.16	77	71	19.2	39	2.02	15.51	2.48	6.57
CC 35	3308	4962	150.74	74	75	19.8	44	2.20	17.33	2.80	6.40
CC 37	3068	4648	151.15	74	69	18.9	40	2.10	15.62	2.84	5.64
CC 67	2946	4810	162.12	78	68	18.1	38	2.08	15.02	3.09	4.87
CC 700	3111	5233	167.02	80	66	17.8	36	2.04	14.36	3.05	4.71
CU 206	3139	4845	154.50	75	68	17.8	40	2.25	16.61	3.22	5.37
CU 208	2852	4556	158.55	77	68	18.6	39	2.09	13.61	3.74	3.72
CU 213	3192	5277	164.76	80	70	19.0	39	2.07	16.49	2.82	5.93
CU 219	2958	4936	165.88	80	70	18.7	38	2.05	14.18	3.13	4.66
CU 220	2803	4278	151.19	74	68	17.8	39	2.18	15.09	3.34	4.59
GF 318	3122	5139	163.40	79	71	19.3	39	2.02	16.43	3.05	5.40
GL 26H	3200	4974	154.88	76	71	18.4	37	2.02	19.00	2.64	7.27
GL 309	3181	5328	166.77	80	70	18.9	38	2.01	14.60	3.19	4.78
GL 365	3228	5342	166.68	80	72	19.8	40	2.04	17.19	2.94	6.01
GL 394	3472	5198	147.73	73	71	20.2	40	1.98	18.37	2.27	8.47
GL 395	2849	4406	152.33	74	68	18.9	39	2.09	13.96	3.39	4.23

Table 3-9. *(continued)*

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. to Alk.
GL 398	3299	5434	164.42	80	72	19.7	39	1.99	17.88	2.78	6.66
GL 976	3262	5526	168.35	81	71	18.2	37	2.04	16.89	2.97	5.94
K 326	3185	5310	165.31	80	70	18.6	36	1.91	17.12	2.80	6.27
K 346	3022	4590	152.49	74	68	18.0	37	2.05	13.96	3.12	4.68
K 730	2951	4631	156.86	76	68	18.3	36	1.99	17.10	2.91	6.03
NC 1226	3327	5236	157.91	76	72	18.8	39	2.04	16.59	2.75	6.08
NC 196	3329	5395	161.34	78	70	18.7	38	2.05	15.54	2.88	5.51
NC 297	3353	5167	154.15	75	71	17.9	37	2.06	17.50	3.13	5.92
NC 299	3036	4937	162.95	78	73	18.4	37	2.00	16.23	2.92	5.60
NC 606	2951	4669	158.30	77	70	18.1	38	2.10	16.48	3.00	5.67
NC 71	3294	5220	158.63	77	70	18.7	36	1.95	16.34	2.97	5.67
NC 72	3162	4747	151.24	74	68	18.1	38	2.10	16.09	2.82	5.76
NC 925	3210	4826	149.41	73	70	18.4	37	1.99	17.28	2.80	6.30
NC 938	3001	4416	146.24	71	70	18.7	40	2.12	12.10	3.09	3.99
NC 970	3646	6375	173.84	82	72	19.8	39	1.97	16.74	2.58	6.75
NC 971	3200	5539	172.42	82	71	19.3	39	2.02	16.34	2.57	6.52
NC 972	3345	5823	173.81	83	70	18.3	38	2.05	15.36	2.82	5.74
NC 978	3226	5366	166.41	80	70	19.1	41	2.12	17.42	2.49	7.17
PVH 1452	2818	4662	163.42	79	69	18.4	37	2.01	14.56	2.99	4.97
PVH 1600	3009	4741	159.02	77	71	19.4	39	1.99	14.70	3.04	4.98
PVH 1920	3052	4663	152.06	74	70	19.5	39	1.97	15.29	2.91	5.40
PVH 2110	2941	5036	170.39	81	74	20.2	41	2.02	16.62	2.49	6.94
PVH 2254	3193	4948	155.64	76	69	19.3	39	2.04	15.61	2.72	5.93

Table 3-9. *(continued)*

Variety	Yield (lb/a)	Value ($/a)	Price ($/cwt)	Grade Index	Days to Flower	Leaves per Plant	Plant Height (in.)	Leaf Spacing (in.)	Sol. Sug. (%)	Total Alk. (%)	Ratio Sug. to Alk.
PVH 2275	2852	4616	161.24	78	70	18.5	38	2.05	15.06	2.93	5.25
PVH 2310	2699	4537	166.79	81	69	18.8	39	2.10	12.70	2.83	4.54
PVH 2360	3057	4635	149.42	72	70	18.9	40	2.14	15.71	3.40	4.69
PVH 1015	3179	5274	166.25	80	70	19.0	38	2.01	15.31	3.06	5.17
XHN 58	2900	5034	172.39	82	68	18.6	39	2.08	15.44	2.70	5.78
Test Average	3096	5002.02	161.05	78	70	18.8	39	2.05	15.88	2.92	5.66

Table 3-10. NC State University post-buyout grade index and 2019 price index

Company Buying Grade	USDA Grade	Post-Buyout Grade Index (1-100)	2019 Price Index ($/CWT)
P1	P2F, P3F, P2L	85	170
P2	P3L, P4F	80	160
P3	P4L	70	140
P4	P5L, P5F	50	115
P5	P4G, P5G, N1L, N1GL	20	65
X1	X1F, X2F, X1L, X2L	90	170
X2, X1H	X3F, X4F, X3L	85	160
X3, X2H, X3H	X4L, X3KM, X3KR, X5F	70	140
X4	X5L, X4KR, X3V, X4V, X4KL, X4KF, X4KM, X3S	50	112
X5	X4KV, X4GK, X4G, X5G, N1XL, N1XO	25	65
C1	C1F, C2F, C1L, C2L	95	190
C2, C1H	C3F, C4F, C3L	90	185
C3, C2H, C3H	C5F, C4L, C4KR	80	158
C4	C5L, C4KM, C4KL, C4KF, C4V, C4S	60	122
C5	C4G, C4GK	30	75
B1, B1X, B2X	B1L, B2L, B1F, B2F, B1FR, B2FR	100	215
B2, B1H	B3F, B3K, B3FR, B4FR,	95	206
B3, B2H, B3H	B3L, B4F, B4K	85	188
B4	B4L, B3KM, B3KR, B4KM, B4KR	75	145
B5	B3V, B4V, B3KF, B3KL, B3S, B5L, B4S	60	120
B6	B4KL, B4KF, B5V, B5KL, B4KV, B5KV, B4GK, B5GK, B4G, B5G	40	70
BT	N1BO, N1R, N1GR, N1GG, N2	20	70
T, T1X	H3F, H4F, H4FR, H4K	100	213
T2, T2X	H5F, H5FR, H5K, B5FR	95	205
T3, T1H, T2H	B5F, B5K	90	185
T4, T3H	B5KR, B5KM	75	135
T5	B6K, H6K, N1K	60	100
T6	B6KV, N1KV	40	60

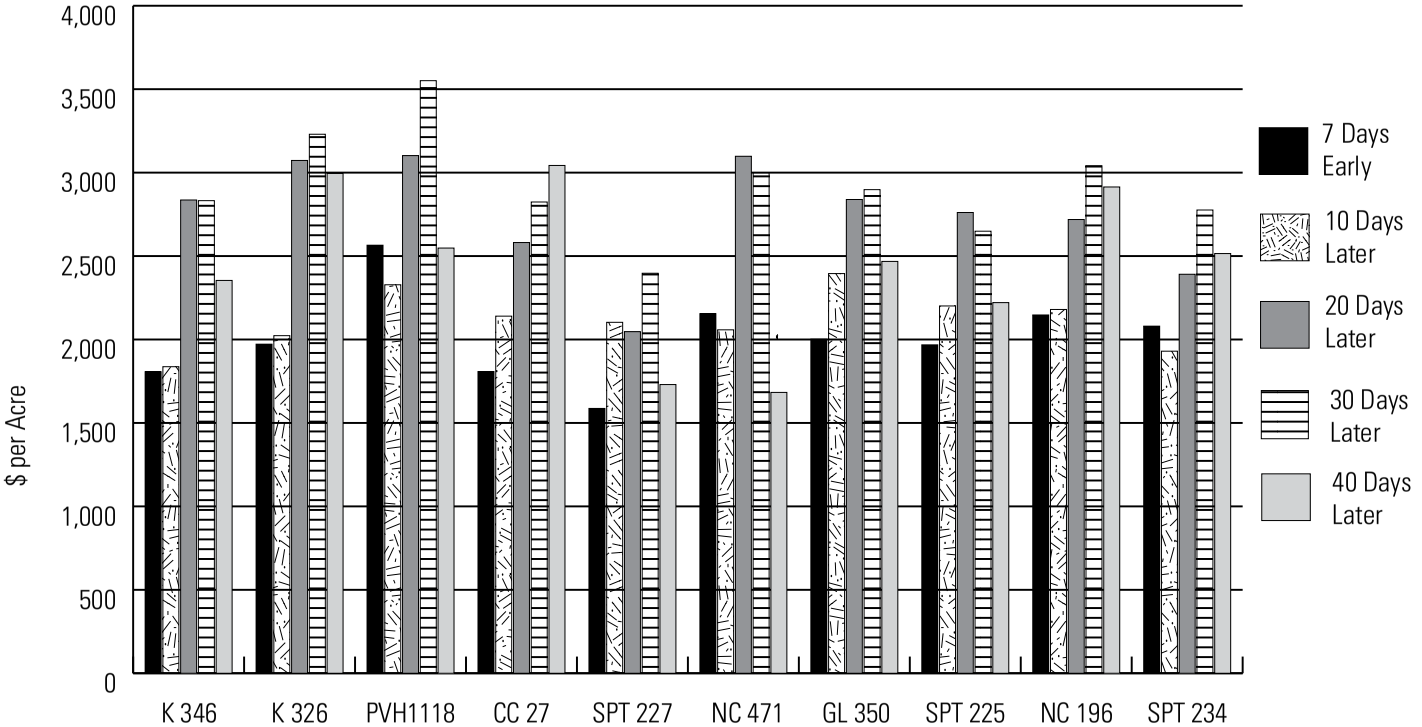

Figure 3-2. Effect of harvest schedule on the value of last priming, 2008

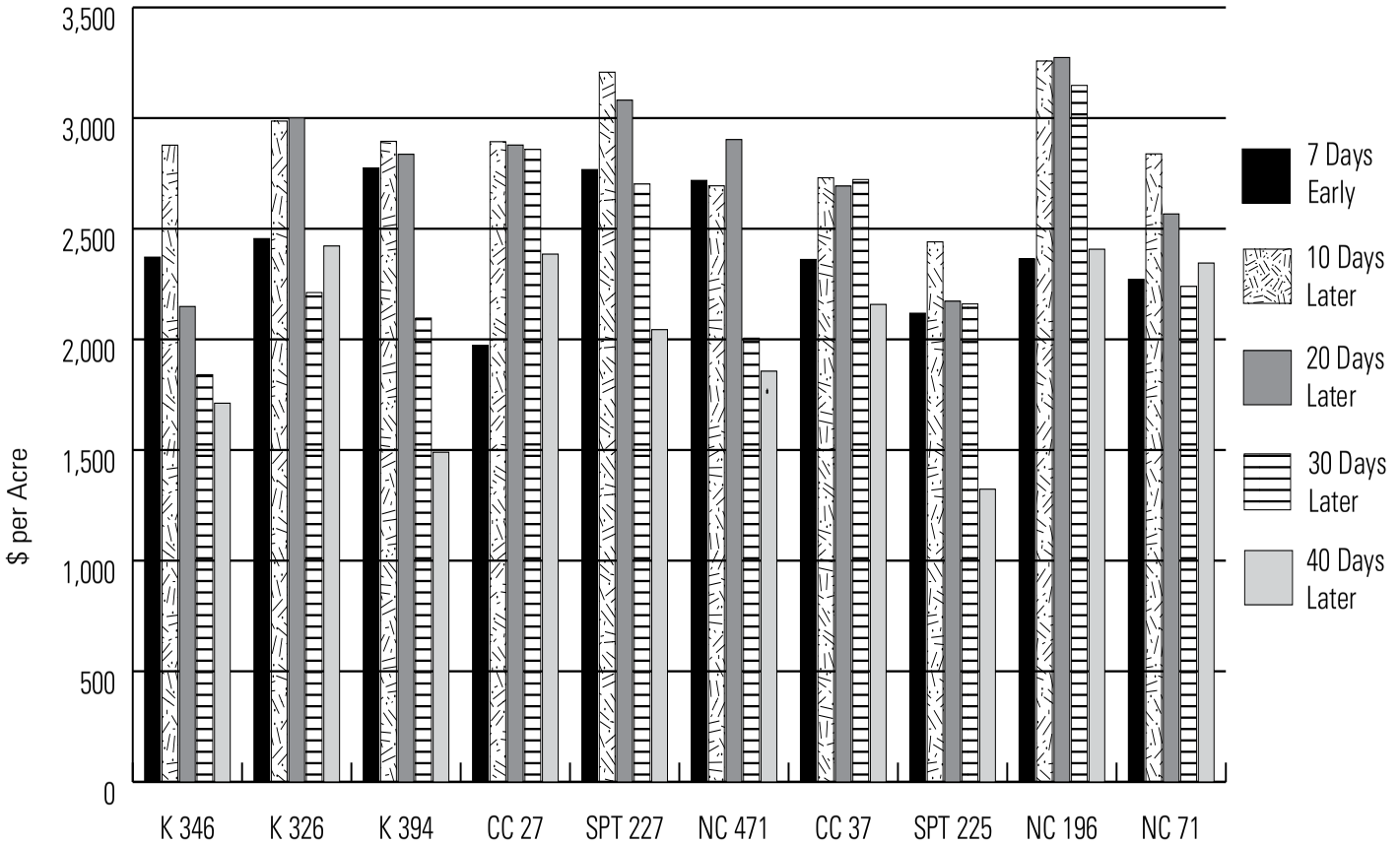

Figure 3-3. Effect of harvest schedule on the value of last priming, 2009

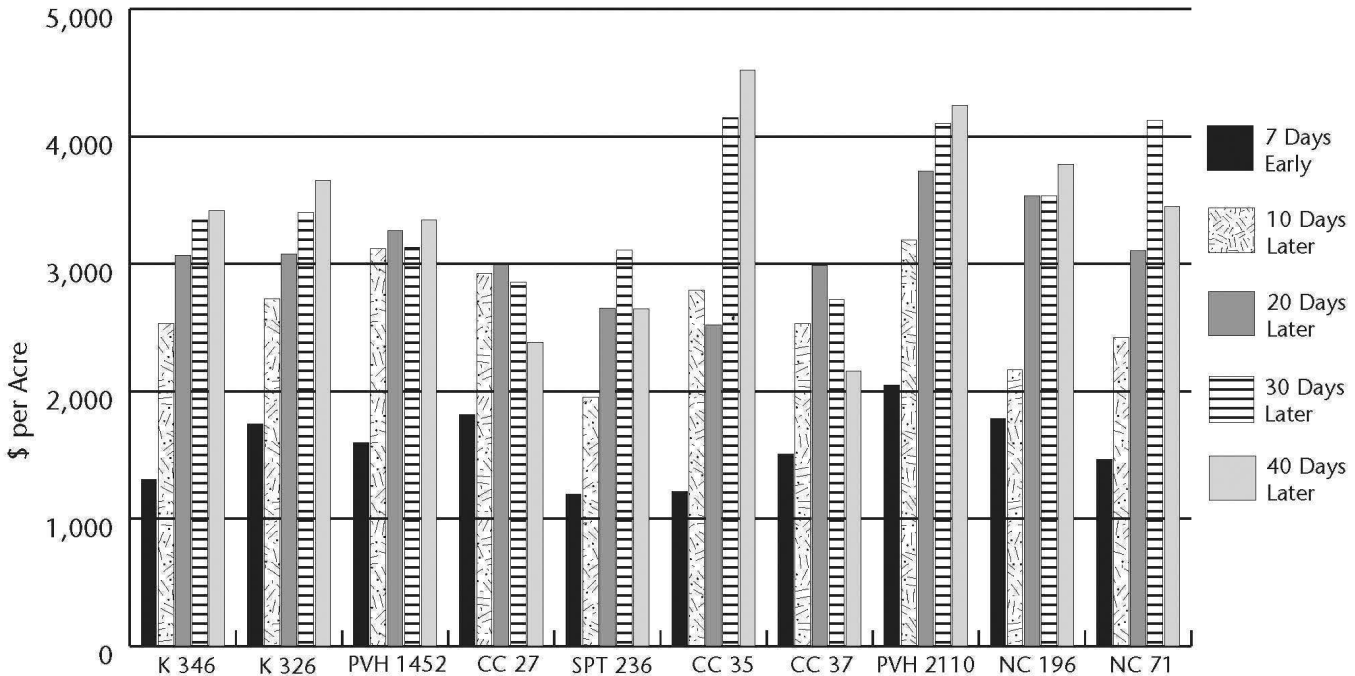

Figure 3-4. Effect of harvest schedule on the value of last priming, 2010

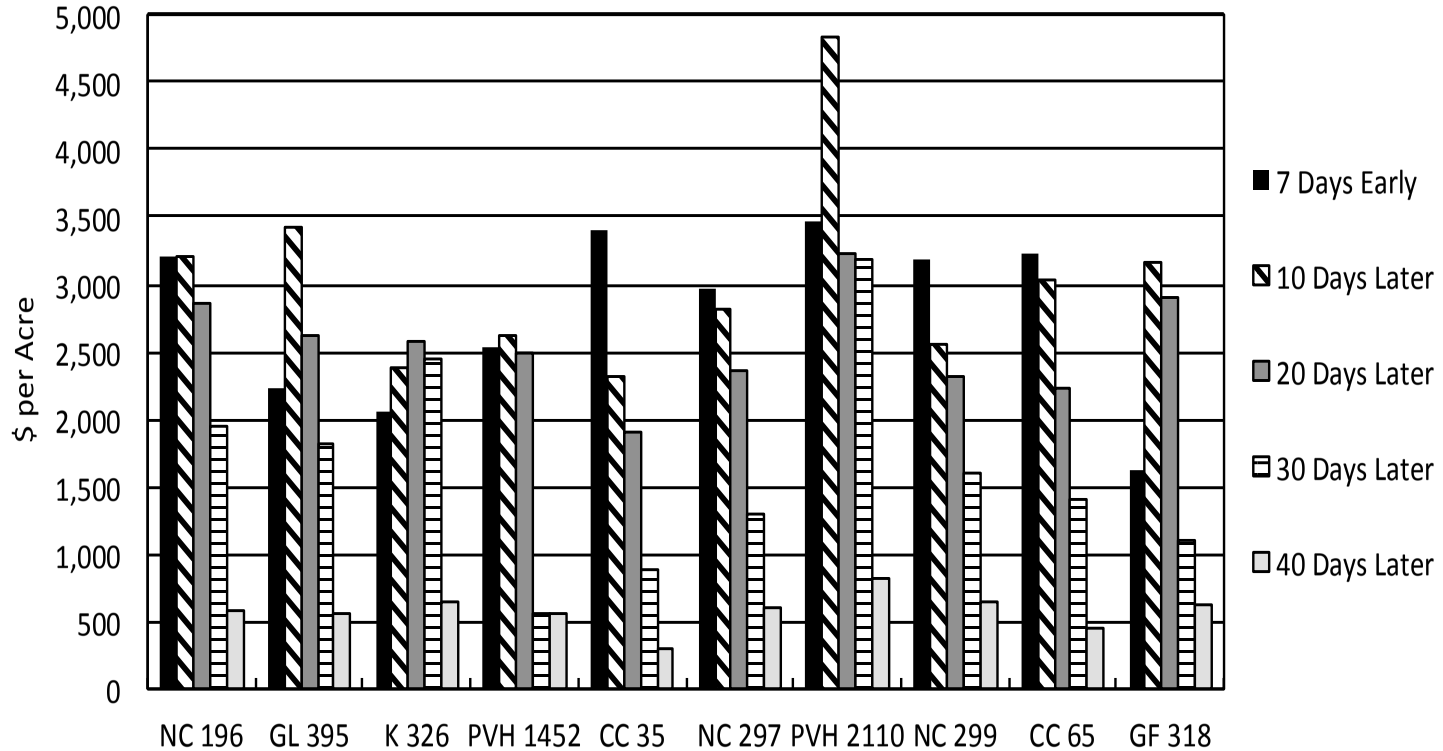

Figure 3-5. Effect of harvest schedule on the value of last priming, 2011

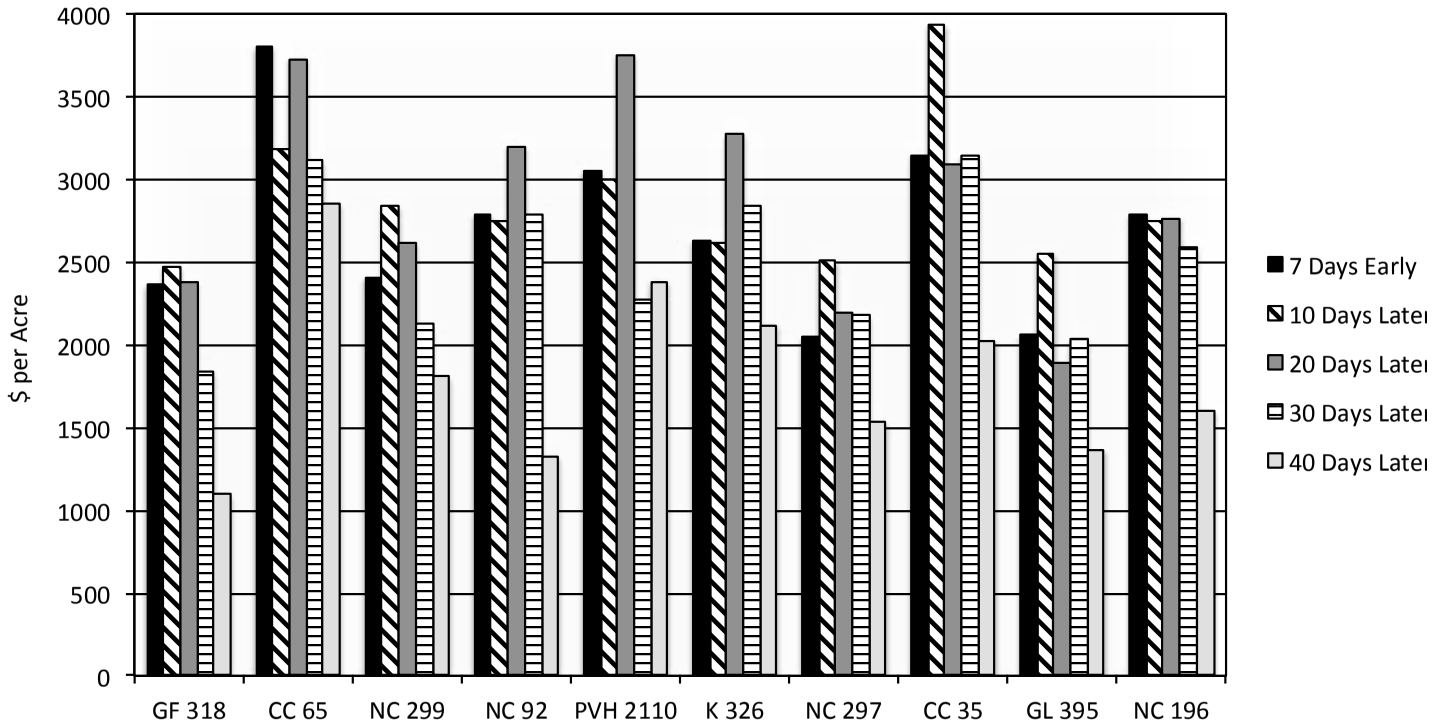

Figure 3-6. Effect of harvest schedule on the value of last priming, 2012

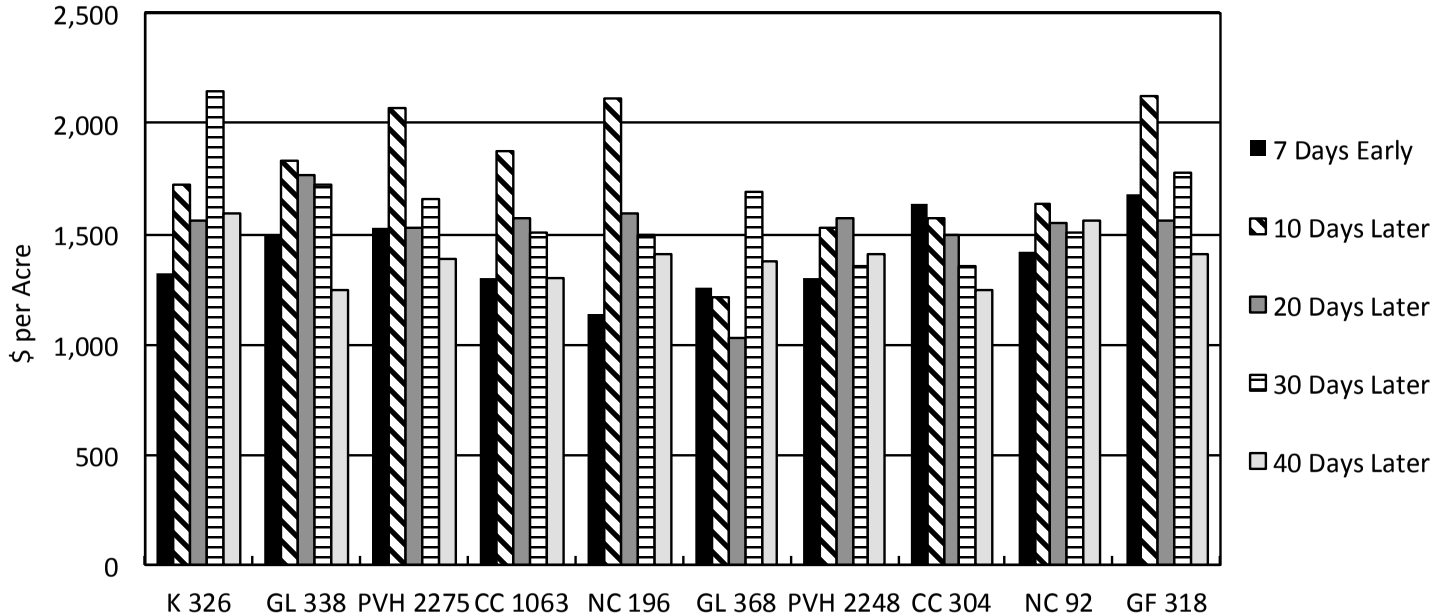

Figure 3-7. Effect of harvest schedule on the value of last priming, 2013

4. PRODUCING HEALTHY TRANSPLANTS IN A FLOAT SYSTEM

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Profitability remains a concern to many growers as a result of rapidly increasing production costs. The first step in minimizing heating-fuel costs is to avoid seeding too early. Most growers have learned that it only takes 60 days to produce a transplant, and that seeding before the second week in February increases fuel usage and the cost of transplant production.

Nearly all of the costs in transplant production are on a whole-greenhouse basis. Thus, the best way to decrease the cost on a per-transplant basis is to increase usability. Therefore, management practices that improve stands and promote uniform growth decrease production costs. Nearly all management practices affect usability, but these are some of the most important:

1. **Consider the materials.**
   - Analyze the water source and manage alkalinity.
   - Select a uniform, high-quality growing medium with a low and well-mixed nutrient charge.
   - Consider tray design.
   - Use seeds with high germination rates and acceptable pelleting materials.
2. **Promote uniform emergence.**
   - Sow seeds during sunny periods.
   - Fill trays uniformly.
   - Place seeds uniformly (in the center of the dibble).
   - Provide a warm temperature (68°F to 70°F at night).
   - Control ants and mice.
3. **Promote uniform growth.**
   - Monitor fertilizer salts in the medium and leach with water from overhead when necessary.
   - Continue to analyze water and manage alkalinity when necessary.
   - Clip properly.
   - Manage insects and diseases.

4. **Prevent stand loss.**
   - Provide proper ventilation and airflow to prevent heat injury.
   - Avoid early seeding, high nitrogen rates, and hot daytime temperatures that promote stem rot diseases.
   - Fumigate trays with methyl bromide or purchase new trays.

CONSIDER THE MATERIALS

Analyze the Water Source and Manage Alkalinity

Water quality management is an important part of successful transplant production. Bicarbonate levels (alkalinity) are high in water from many areas, particularly in eastern counties, and boron is absent from the water in many counties in the piedmont. Have a water sample analyzed from each potential water source before beginning transplant production.

The North Carolina Department of Agriculture and Consumer Services (NCDA&CS) analyzes water at a nominal cost. Growers receive a detailed report about the nutritional suitability of each water sample for transplant production.

Collect a 20-ounce sample from each potential water source. A clean, nonreturnable drink bottle with a screw-on cap makes an excellent sample bottle. Rinse the bottle (but do not use soap) several times and allow the water to run several minutes before collecting the sample. Forms and assistance are available from county Cooperative Extension centers.

Wells usually provide the most desirable water. Municipal sources are also satisfactory, but the water occasionally requires acidification to reduce bicarbonates. Avoid pond or river water unless it comes from a municipal source due to potential contamination with disease-causing organisms. Herbicides that injure tobacco also could be carried by soil runoff into farm ponds.

Select a High-Quality Growing Medium

Typical tobacco media consist primarily of peat combined with vermiculite and perlite in various proportions. Consider a medium's particle size distribution and nutrient charge to determine its suitability for transplant production. Particle size in a soilless medium is similar to soil texture and is determined by the relative amounts and size of the mix's components. The particle size distribution of a medium determines many characteristics that are important in plant growth, such as aeration, water holding capacity, drainage, and capillarity (wicking). Research has shown that a wide range of particle sizes is suitable. After you find a medium with a good range of particle sizes for tobacco production, make sure that it is free of sticks, stems, clods, and weed seeds. Evaluate its moisture content, uniformity, and fertilizer charge.

Consider Tray Design

A significant factor affecting tray cost to the grower is the cost of fuel. High natural gas prices have increased the cost of manufacturing, while high fuel prices have increased the cost of transportation and delivery.

Tray costs have always been an issue outside the United States because of shipping costs. Polystyrene trays are light, but they are bulky, which makes them expensive to ship. The high cost of growing medium is also a factor overseas. One way to reduce production and shipping costs is to decrease the depth of the tray, which allows more trays to be placed in a shipping container or on a truck. Shallower trays have the additional advantage of requiring less growing medium to fill the cell, which decreases the cost to a grower. Less on-farm storage space is required for shallow trays than for traditional-depth trays.

A few years ago, a glazed tray was introduced that has hardened sidewalls within the cell, which are formed by superheating during the manufacturing process. The idea is that the hardened sidewalls will resist root penetration and be easier to sanitize. However, the tray depth is slightly shallower than a traditional 288-cell tray. This difference in depth results in slightly smaller cells (15 cubic centimeters versus 17 to 17.5 cubic centimeters), which partially offsets the cost of glazing and decreases growing medium requirements by 12 percent. Observations suggest that fewer roots penetrate the tray, but research has not been conducted to determine if disease incidence is different with plants produced in glazed trays versus those produced in traditional trays.

Research has measured the effects of cell density and volume on transplant production (tables 4-1 and 4-2). Researchers compared four trays differing in cell density and volume filled with three different growing media. They compared the the following trays:

1. A glazed 288-cell tray with a cell volume of 15 cubic centimeters and cell density of 122.5 cells per square foot in 2004 and a traditional 288-cell tray with a cell volume of 18 cubic centimeters and cell density of 122.5 cells per square foot in 2005.

2. A shallow, glazed 288-cell tray with a cell volume of 8.6 cubic centimeters and cell density of 122.5 cells per square foot.

3. A traditional 200-cell tray with a cell volume of 27 cubic centimeters and cell density of 85 cells per square foot.

4. A shallow 200-cell tray with a cell volume of 8.6 cubic centimeters and a cell density of 85 cells per square foot.

Results indicate that 200-cell trays produced larger plants than 288-cell trays. However, there were no differences in plant size due to tray depth. Thus, in a float system, cell density is more important than cell depth (root volume) in affecting plant size. These results indicate that shallow trays can be used without reducing transplant quality and that all media evaluated would be suitable for shallow trays.

Table 4-1. Effect of cell volume and density on transplant production in the float system, 2004

Treatment	ISM[1] (%)	Spiral Root (%)	Total Plants (%)	Usable Plants (%)	Stem Length (cm)	Stem Diameter (mm)
Trays						
Glazed 288 traditional (15 cc per cell)	95	3	94	88	6.4	3.0
Glazed 288 shallow (8.6 cc per cell)	96	4	92	84	6.3	3.0
200 traditional (27 cc per cell)	96	3	95	90	7.0	3.6
200 shallow (8.6 cc/cell)	95	3	94	87	7.0	3.8
LSD (0.05)	NS	NS	NS	4	0.3	0.3
Growing Medium						
Carolina Gold	95	3	94	87	6.6	3.3
Carolina Choice	96	4	94	88	6.5	3.4
All peat, aggregate free—experimental	96	4	93	86	6.8	3.3
LSD (0.05)	NS	NS	NS	NS	NS	NS

[1] ISM = Modified Index of Synchrony, which is a measure of the uniformity of germination. It is calculated as the percentage of the total germination that occurred over a 48-hour period.
NS = Not statistically significant. Treatments should be considered similar.

Table 4-2. Effect of cell volume and density on transplant production in the float system, 2005

Treatment	Emergence (%)	Total Plants (%)	Usable Plants (%)	Stem Length (cm)	Stem Diameter (mm)
Trays					
288 traditional (17.5 cc per cell)	94	90	79	4.9	2.5
Glazed 288 shallow (8.6 cc per cell)	96	91	81	5.9	2.4
200 traditional (27 cc per cell)	94	91	84	6.2	2.9
200 shallow (8.6 cc/cell)	94	92	84	6.1	2.9
LSD (0.05)	2	NS	NS	0.4	0.3
Growing Medium					
Carolina Gold	93	87	78	5.7	2.6
Carolina Choice	95	93	84	5.8	2.6
All peat, aggregate free—experimental	95	93	84	5.9	2.7
LSD (0.05)	2	5	4	NS	NS

NS = Not statistically significant. Treatments should be considered similar.

PROMOTE UNIFORM EMERGENCE

Uniform emergence and growth are necessary to produce a high percentage of usable transplants. Research has shown that even a three-day delay in emergence in 25 percent of the seedlings could reduce usability (Table 4-3). The researchers seeded random cells within a tray 3, 5, 7, or 12 days after seeding the rest of the tray. In general, the delayed treatments produced fewer usable seedlings than the initial seeding. These results show the importance of uniform emergence and that clipping will not correct the uneven growth from delayed emergence.

Table 4-3. Effect of staggered seedling emergence on transplant production, 1999–2000

Treatment	Total Stand at Day 50 (%)	Usable Transplants at Day 50 (%)
1999 Experiment		
Check (100% seeded day 1)	89 a	76 a
75% seeded day 1, 25% seeded day 5	89 a	59 b
75% seeded day 1, 25% seeded day 7	90 a	66 ab
75% seeded day 1, 25% seeded day 12	80 b	65 ab
2000 Experiment		
Check (100% seeded day 1)	95 a	91 a
75% seeded day 1, 25% seeded day 3	96 a	85 b
75% seeded day 1, 25% seeded day 5	97 a	78 c

Note: For each experiment, averages followed by the same letter in a column are not statistically different and should be considered similar.

Fill and Seed Trays Uniformly

Begin seeding 50 to 55 days before the anticipated transplanting date using only high-quality, pelleted seeds. Make sure that one seed is placed in each cell. Misting trays from overtop after floating has not been shown to speed seedling emergence. However, the use of a premoistened medium decreases the amount of medium that falls through the holes in the bottom of the tray and increases the speed of emergence as compared to a dry medium. Overly wet media do not flow from the hopper box as uniformly as dry media. Be sure the trays are filled uniformly.

Wet new trays before filling them, and screen the planting medium if it contains sticks and clods. Use a moist medium, and pack the medium all the way to the bottom of the cell. Research indicates that taking these precautions will help to prevent dry cells within a tray. Dry cells create a common problem in float systems, particularly with new trays, because they float higher than old trays and because it is difficult to keep the medium from falling through the hole in the bottom of the tray.

Provide a Warm Temperature

The ideal germination temperature for tobacco seeds is approximately 68°F at night and 86°F during the day. Fuel use decreases 15 percent for every five-degree reduction in temperature.

Therefore, after maximum seedling emergence is obtained, nighttime temperatures should be reduced to a range of 55°F to 60°F to conserve fuel usage. Daytime temperatures of 80°F to 85°F are adequate for normal growth. Heat injury (browning of leaves or seedling death) has been observed when air temperatures inside the structure exceed 110°F.

Different varieties respond in various ways to germination temperature, and it is very common to see differences in germination rate among varieties in the same greenhouse. The response of three popular varieties to temperature during germination is shown in Figures 4-1 through 4-6. In all varieties the germination was earlier at 68°F night and 86°F day than at 68°F night and 95°F day. However, the delay in germination from high temperatures differed greatly among varieties and, in some cases, between seed lots within a variety. These data show that higher than ideal temperatures, even as low as a 95°F day, can delay emergence, reduce uniformity of emergence, and sometimes even decrease total emergence. For a variety such as K 326, the delay in emergence at high temperatures is relatively small. However, for NC 71 and NC 297, the delay in germination is significant. It is important to remember that these studies were conducted in an incubator. Response to high temperature stress in a greenhouse will be greater because delayed germination makes the plants more susceptible to salt injury and disease.

While research has shown 68°F night and 86°F day to be the most favorable temperatures for germination in all tested varieties, it is very common to observe a range of germination times among varieties. Studies conducted with seed from the 2003 Official Variety Test found that most varieties reached maximum germination in seven to eight days when exposed to ideal temperatures of 68°F night and 86°F day. However, the range among varieties was from 6 to 13 days. The germination of most varieties was delayed by 1 day when the daytime temperature was increased from 86°F to 95°F. However, the germination of NC 71 was delayed by 2 days (from 9 days to 11 days).

PROMOTE UNIFORM GROWTH

Monitor and Manage Fertilizer Salts in the Growing Medium

Fertilizer salts injury is the most common nutritional problem in float systems. Fertilizers supply nutrients in the form of salts. When fertilizer is added to the waterbed, these salts dissolve in the water. Then the nutrients move into the growing medium as water is absorbed from the waterbed.

High temperatures, low humidity, and excessive air movement promote water evaporation from the surface of the growing medium, which results in accumulation of fertilizer salts in the medium in the top of the cell. Salts can reach levels high enough to injure seedlings, even when recommended fertilization programs are followed (Figure 4-7). Fertilizer salts levels in the upper half inch are directly related to the total amount of fertilizer applied (in the waterbed and in the medium). Therefore, it is better to use a medium with no fertilizer (or with only a minimal amount) than to use a highly charged medium.

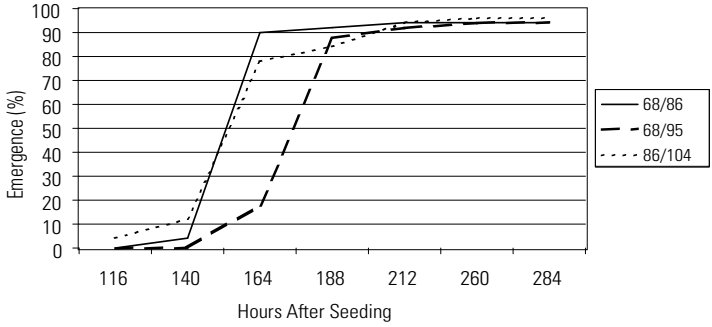

Figure 4-1. Effect of temperature on the germination of K 326 (2003)

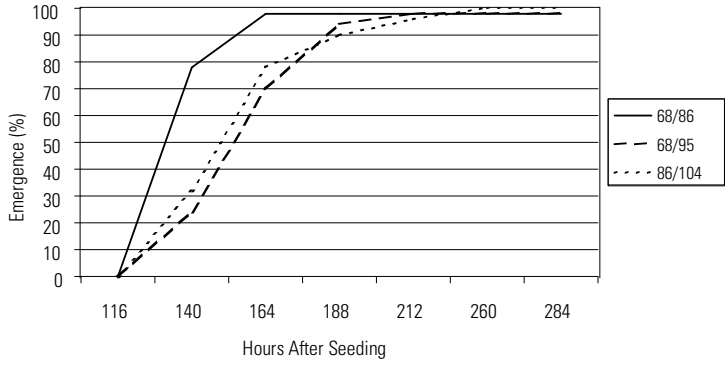

Figure 4-2. Effect of temperature on the germination of K 326 (2004)

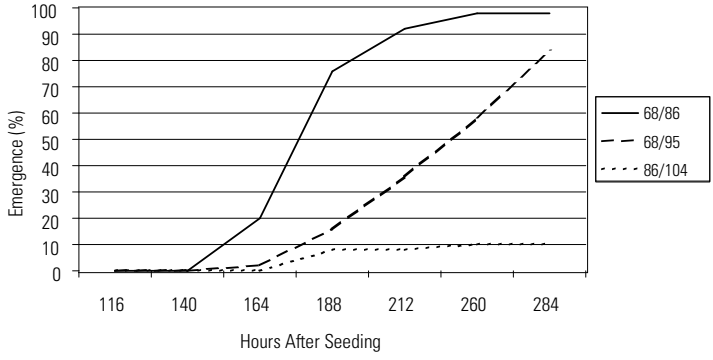

Figure 4-3. Effect of temperature on the germination of NC 71 (2003)

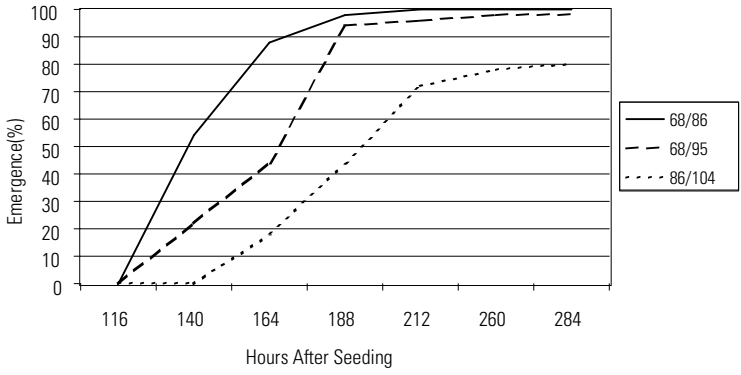

Figure 4-4. Effect of temperature on the germination of NC 71 (2004)

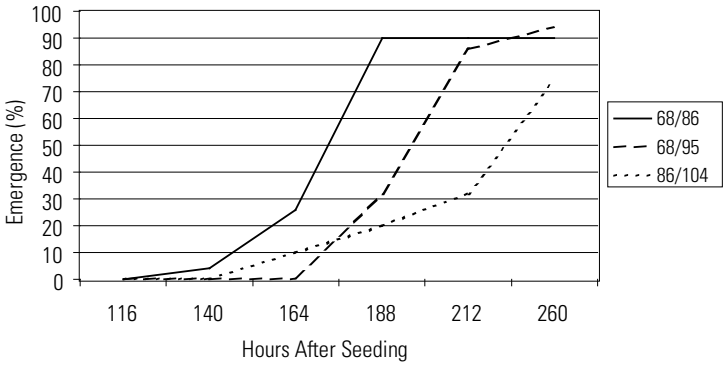

Figure 4-5. Effect of temperature on the germination of NC 297 (2003)

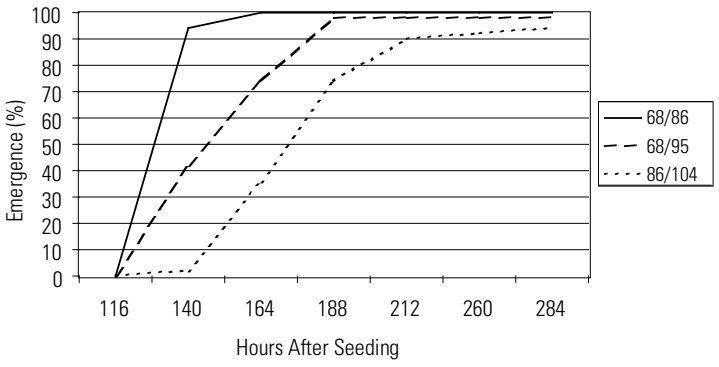

Figure 4-6. Effect of temperature on the germination of NC 297 (2004)

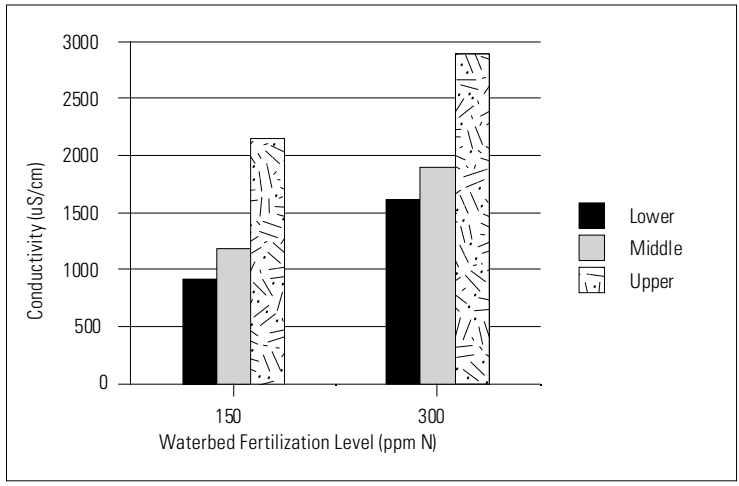

Figure 4-7. Conductivity of a soilless medium at two fertilization levels and at three depths in the cell

Electrical conductivity is a commonly used indicator of fertilizer salts levels in media and water. Pocket-sized conductivity meters are available for a reasonable price from many farm supply dealerships. When properly calibrated, these meters are very helpful in a salts-monitoring program for float water and growing media.

Salts should be monitored in the growing medium every 24 to 48 hours from seedling emergence until the plant roots grow into the waterbed. Collect a sample of the medium from the upper half inch of the cell from several trays, then add twice as much distilled water as growing medium on a volume basis (a 2:1 water-to-growing-medium dilution). Shake or stir the sample and wait two to three minutes before measuring the conductivity. Normal levels range from 500 to 1,000 microseimens (0.5 to 1 millimhos). Readings of 1,000 to 1,500 microseimens (1 to 1.5 millimhos) are moderately high, and readings above 1,500 microseimens are very high. Apply water from overhead to leach and dilute salts when: (1) conductivity readings are above 1,000 microseimens and plants are pale or stop growing; or (2) conductivity readings are 1,500 microseimens or above.

Fertilize Properly

Growers with fertilizer injection systems have been successful in using a constant application rate of 125 parts per million (ppm) nitrogen from 20-10-20, 16-5-16, or similar ratio fertilizers. For noninjected systems, fertilizer can be added to the water in two steps. Research has shown that excellent transplants can be obtained from an initial application of fertilizer to supply 100 to 150 ppm nitrogen within seven days after seeding plus a second application to supply 100 ppm nitrogen four weeks later. Use a complete fertilizer (with 2-1-2 or 3-1-3 ratio) for the first application. The same fertilizer or ammonium nitrate can be used for the second application. Higher application rates cause tender, succulent seedlings that are more susceptible to diseases. Also, high application rates promote fertilizer salts injury to seedlings as noted above. If high

fertilizer salts levels are detected during the first four weeks after seeding (>1,000 microseimens in the medium from the upper half inch of the cell), apply water uniformly from overtop to reduce fertilizer salts levels.

Monitoring waterbed fertility levels. Pocket-sized conductivity meters can be used to monitor fertility levels in waterbeds. Most fertilizer labels contain a chart that provides the expected conductivity level for the initial fertilizer concentration, usually expressed as nitrogen concentration in ppm. Conductivity is useful in measuring the accuracy of fertilizer injectors and how well the fertilizer is mixed throughout the waterbed. Conductivity measurements can also provide a rough estimate of the general fertility status in a waterbed throughout the growing season. It is important to understand that while the chart lists nitrogen concentration, the meter is measuring total conductivity from all salts (nutrients). Therefore, as the season progresses and plants adsorb nutrients from the waterbed at different rates (and water levels fluctuate), the relationship between conductivity and nitrogen concentration becomes less dependable (Figure 4-8). Therefore, collecting a water sample for analysis by the NCDA&CS (or another laboratory) is the only way to get an accurate measure of the concentrations of all nutrients in the waterbed.

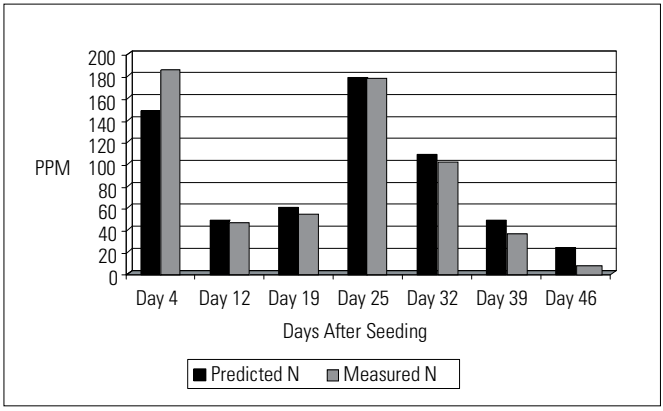

Figure 4-8. A comparison of predicted (based on conductivity) and measured nitrogen concentrations in a float bed, 2002

Nitrogen form. Fertilizers commonly provide nitrogen from various combinations of nitrate, ammonium, and urea sources. Tobacco seedlings can use nitrogen in the nitrate and ammonium forms, but urea must be converted to ammonium before the nitrogen can be used by the plant.

Research has shown reduced seedling growth when more than half of the nitrogen in a fertilizer was provided from urea, as compared to all of the nitrogen being supplied as nitrate and ammonium. Similar results have been observed at the University of Kentucky, where Bob Pearce suggests that reductions in plant growth may be a result of nitrite toxicity. Nitrite is an intermediate nitrogen form that occurs when ammonium converts to nitrate. Nitrite can accumulate to levels high enough to cause plant injury when high levels of ammonium are present.

Exclusive use of nitrate nitrogen has been observed to raise the pH of the medium, which causes plant-growth problems similar to those caused by bicarbonates. Therefore, study the fertilizer label carefully to determine the nitrogen form as well as the concentration of nitrogen and micronutrients. The best choice is a fertilizer that contains a balance of nitrogen in the ammonium and nitrate forms.

Phosphorus. Research at Clemson University has shown the need to limit phosphorus concentrations to 35 to 50 ppm in the waterbed. Applying excess phosphorus causes spindly transplants and leaves more phosphorus in the waterbed for disposal after transplant production. Therefore, 20-10-20 and 20-9-20 are better choices than 20-20-20 fertilizer. Other fertilizers, such as 16-5-16, are also good choices because very little phosphorus is left in the float water after the transplants are taken to the field.

Sulfur. A sulfur deficiency is occasionally observed in float systems when the medium was not supplemented with magnesium sulfate (Epsom salts) or calcium sulfate (gypsum) and sulfur was not provided by the fertilization program. The major media marketed for tobacco should contain sulfur. Also, some fertilizers such as 16-5-16 contain sulfur. If the sulfur content in a medium is questionable, the fertilizer used does not contain sulfur, or a sulfur deficiency is observed, add Epsom salts to the waterbed at a rate of four ounces per one hundred gallons of water.

Boron. A boron deficiency causes bud distortion and death and has been observed in several float systems. In most cases, the water and the fertilizer did not contain any boron. The best solution to this situation is to choose a fertilizer such as a 20-10-20 with a guaranteed micronutrient charge if the water analysis indicates no boron. If a fertilizer with boron is unavailable, adding no more than 0.25 ounce of Borax per 100 gallons of float water should prevent a deficiency.

Organic fertilization. In recent years, some growers have contracted to grow tobacco organically. Studies were conducted to compare seedling production when using bat manure (8-4-1) and Peruvian seabird guano (13-8-2) to seedling production when using the standard water-soluble fertilizer 16-5-16 (Table 4-4).

Table 4-4. Effect of fertilizer on stem length and transplant usability, 2002 and 2003

	Stem Length (cm/plant)		Usable Transplants (%)	
Fertilizer	**2002**	**2003**	**2002**	**2003**
16-5-16	8.7	5	73	88
Bat manure (8-4-1)	2.6	1	0	0
Peruvian seabird guano (13-8-2)	6.8	3	77	72
Bat manure (8-4-1) at a 3× rate	—	3	—	84

Results show that seabird guano is a better choice than bat manure when both are applied at the normal rate. Only 33 percent of the nitrogen in bat manure is in a plant-available form, which resulted in small, nitrogen-deficient seedlings when used at the normal rate. Tripling the bat manure rate to compensate for reduced availability resulted in seedlings comparable to the seabird guano seedlings. However, a 3× rate of bat guano is very expensive.

Both organic products produced smaller seedlings and a lower percentage of usable seedlings than 16-5-16 in one study, but in another study the seabird guano and 16-5-16 produced similar percentages of usable transplants. Based on these results, the Peruvian seabird guano seems to be a better choice than bat manure for organic seedling production. Growers using seabird guano should monitor alkalinity levels in the waterbed closely and correct when necessary.

Various formulations and brands of seabird guano exist; however, those most commonly used by tobacco producers are high in organic nitrogen and phosphorus and low in potassium (e.g., Sunleaves 12-11-2). Many producers have expressed concern with the use of fertilizer sources high in organic nitrogen due to the negative effects the source can have on seedling development, specifically as urea is released from the nutrient source. In addition, as producers add seabird guano to the float water at rates designed to supply sufficient nitrogen (typically 125-150 ppm N), they often over-supply phosphorus (by as much as 3x) and under-supplying potassium (by as much as -6x). Furthermore, tobacco float beds fertilized with seabird guano often contain extremely high concentrations of bicarbonate (HCO_3^-) which can increase water pH, limit nutrient availability, and reduce seedling growth/vigor.

In order to improve nutrient recommendations for organic tobacco seedling producers, research was conducted to evaluate three organic nitrogen (N) programs that might serve to address the following:

1. Provide sufficient N for seedling growth
2. Limit phosphorus exposure
3. Reduce bicarbonate concentrations (prevent high float water pH)

The three organic N programs evaluated were 100 percent seabird guano (Sunleaves 12-11-2), 100 percent sodium nitrate (SQM Allganic 16-0-0), and a combination of guano and sodium nitrate. Sodium nitrate is mined material from South America that is Organic Materials Review Institute (OMRI)-listed and contains 100 percent nitrate-N. Treatments were supplemented with OMRI-listed water soluble 0-0-52 (potassium sulfate, SQM Allganic). Each fertility program was designed to provide 125 ppm N, 0-115 ppm P, and 125 ppm K. Three additional treatments of each organic N program that included gypsum (calcium sulfate) were also evaluated. Each treatment was compared to a conventional water soluble fertilizer source (SQM 16-5-16). A complete list of treatments and the nutrients supplied by each fertilizer program can be found in Table 4-5.

Table 4-5. Fertilizer programs and the corresponding nitrogen, phosphorus, potassium, and calcium concentrations

Fertilizer Program[a]	N	P	K	Ca	Quantity[b] (oz/100 gal water)
	ppm				
SG + PS	125	115	20(SG) + 105(PS)	0	13.9 (SG) + 2.7 (PS)
SG + PS + Gyp	125	115	20(SG) + 105(PS)	50	13.9 (SG) + 2.7 (PS)
SN + PS	125	0	125 (PS)	0	10.4 (SN) + 3.2 (PS)
SN + PS + Gyp	125	0	125 (PS)	50	10.4 (SN) + 3.2 (PS)
SG + SN + PS	44(SG) + 81(SN)	40	7(SG) + 118 (PS)	0	4.9 (SG) + 6.8 (SN) + 3.0 (PS)
SG + SN + PS + Gyp	44(SG) + 81(SN)	40	7(SG) + 118 (PS)	50	4.9 (SG) + 6.8 (SN) + 3.0 (PS)
16-5-16	125	40	125	0	10.4 (16-5-16)

[a] SG, Seabird Guano; PS, potassium sulfate; SN, sodium nitrate; Gyp, gypsum.

[b] Figures in column represent fertilizer sources presented in the "Fertilizer Program" column. Gypsum not included in figure estimates, but was supplied at 2.90 oz/100 gal to obtain 50 ppm Ca in designated treatments.

Treatments containing sodium nitrate as the sole source of nitrogen failed to produce usable seedlings due to the absence of phosphorus in the selected fertilizer program (Table 4-6) and the low phosphorus (<1.0 ppm) content of the soilless media and source water. Seedling growth and development was acceptable in treatments composed of guano only or guano + sodium nitrate, and was similar to that of 16-5-16 (Table 4-6). In addition, it does not appear that calcium was a limiting production factor; therefore, gypsum was not required for plants to reach optimal transplanting size. Although, it is probable that calcium demand could vary from season to season, based upon growing conditions. Should calcium deficiency develop, producers are encouraged to utilize OMRI-listed sources of gypsum for correction. The use of lime is discouraged, as it may increase the solution pH to a level that the availability of other nutrients in limited–in much the same way as bicarbonate.

Ammonium-N float water concentration was greatest in guano treatments 25 days after seeding (DAS), but declined rapidly over the following 20 to 30 days. The decline in ammonium concentration was complemented by an increase in nitrate-N concentration during the same period, indicating that ammonium was converting into nitrate. Bicarbonate concentration was greatest in guano only (≥12.0 meq/L) and guano + sodium nitrate (≥3.0 meq/L) treatments 25 DAS but was <1.0 meq/L in sodium nitrate–only treatments, further implicating guano as a source of bicarbonate in organic float systems. The established bicarbonate limit is 2.0 meq/L (or 100 ppm), beyond which acidification is recommended. Despite the high bicarbonate concentrations documented in guano-only treatments, seedling growth was not impacted. Ultimately, guano and guano + sodium nitrate based fertility programs produced seedlings comparable to 16-5-16 and appear to be suitable for the production of organic tobacco seedlings. These fertility programs should be managed to include additional nutrients, such as phosphorus, in order to provide a complete nutrition program. Furthermore, bicarbonates should be monitored and corrected accordingly.

Table 4-6. Transplant usability and physical measurements as influenced by organic fertility program[1]

Fertilizer Program[2]	Total Plants	Usable Plants	Stem Diameter (mm/plant)	Stem Height (cm/plant)
	%			
Guano	90 a	78 c	2.76 b	5.62 b
Guano + Gyp	91 a	79 bc	2.84 b	6.08 ab
Sodium Nitrate	--[3]	--	--	--
Sodium Nitrate + Gyp	--	--	--	--
Guano + Sodium Nitrate	91 a	85 ab	3.48 a	6.27 ab
Guano + Sodium Nitrate + Gyp	93 a	86 a	3.43 a	6.47 ab
16-5-16	88 a	79 bc	3.30 a	6.62 a

[1] Treatment means followed by the same letter within the same column are not significantly different.

[2] Guano, Sunleaves (12-11-2) Peruvian Seabird Guano; Sodium Nitrate, Allganic 16-0-0; Gyp, gypsum (Calcium Sulfate). All treatments were supplied with Allganic 0-0-52 to ensure 125 ppm K.

[3] Treatment did not produce usable transplants; therefore, data are excluded from the analysis.

Additional points for consideration:

- Producers might consider processing (grinding) guano prior to application. Smaller guano particles will have more surface area and will be more water soluble, both of which should increase nitrogen release into solution. In addition, soaking and agitating guano in warm water at least 24 hours before application will also promote solubility.
- When blending organic nitrogen sources, target 40 ppm phosphorus (P) from guano (example: 4.85 oz. 12-11-2/100 gallons float water). This will ensure sufficient P for the season when added to the float water in two applications. The remaining nitrogen needed for seedling growth can be sourced from sodium nitrate. Examples of this blend can be found in Table 4-6.
- Consult with your local Cooperative Extension agent if you suspect a deficiency (such as calcium or boron). Organically approved secondary and micronutrient sources are available; however, deficiencies should be confirmed prior to application.
- Consult with your organic certifier and contract holder prior to the use of ANY fertilizer source.
- Water circulation is critical for organic nutrient sources, as some (guano) are not easily dissolved or distributed in solution. Submersible pumps will help circulate water/nutrients and can add oxygen to the float water. The addition of oxygen is recommended, as it will help promote nitrification, reduce bicarbonate concentration, and increase oxygen concentration in the float water.
- 2.90 oz gypsum/100 gallon of float water will add roughly 50 ppm calcium and 40 ppm sulfur.
- Float water samples should be collected and analyzed at frequent intervals (weekly).
- Split-apply organic fertilizer to float beds. The first application should take place 7-10 days after seeding, and the second about two to three weeks later. This will reduce seedling exposure to soluble salts, bicarbonate, urea, and nitrite (NO_2^-).

- Bicarbonate (HCO_3^-) concentration can reach such a level that seedling growth may be negatively affected. One OMRI-approved vinegar source (Green Gobbler) has proven successful in preliminary screening at NC State. Green Gobbler is 30 percent acetic acid, which is much higher in concentration than food-grade vinegar sources, which are typically approximately 5 percent acetic acid. Producers should exercise caution (wear gloves and eye protection) when applying acidifying materials to float water.
- If greenhouse source water is high in bicarbonate, then treatment before seeding is recommended, just as it is in conventional production. For information pertaining to application rates of organic acidifiers, please contact your local Extension agent.

Calculating parts per million. Because nutrient recommendations in the float system are given on a concentration basis, growers must calculate these concentrations as parts per million (ppm). While this is very different from the traditional pounds per acre or pounds per plant bed, it really is not very difficult to calculate. The following formula is a useful way to calculate the amount of fertilizer necessary for a given concentration in the waterbed.

$$\text{Fertilizer added per 100 gallons} = \frac{\text{Concentration}}{\% \times 0.75}$$

Where:
Fertilizer added per 100 gallons = amount of fertilizer to add to each 100 gallons of water in the waterbed;
Concentration = desired concentration in parts per million;
% = concentration of the nutrient in the fertilizer.

Example: *A grower wishes to obtain 100 parts per million nitrogen from 16-5-16. This product is 16 percent nitrogen. Therefore:*

$$\frac{100}{16 \times 0.75} = 8.3 \text{ ounces of 16-5-16 per 100 gallons of water.}$$

Clip Properly

Proper clipping is an important practice that can increase the number of usable transplants and improve transplant hardiness, stem-length uniformity, and stem diameter. A properly clipped plant is essential for carousel transplanters because uniform stem lengths are needed to transplant seedlings at the proper depth, and excessive foliage disturbs the timing mechanism. Clipping can also be used to delay transplanting when field conditions are unfavorable. Research has shown that maximum usability is obtained with three to five clippings. However, many growers clip 15 to 20 times. Too many clippings indicate that the greenhouse was seeded too early. Early seeding increases heating costs as well as the potential for collar rot. Another problem is improper clipping (clipping too early and too close to the bud), which reduces stem length, increases stem rots, and slows plant growth in the field.

Research conducted by Walter Gutierrez of NC State University showed that collar rot infection increased when clipping residue was left on tobacco stems and leaves. Therefore, to reduce the incidence of this disease, remove as much residue as possible. Use high-suction rotary mowers and properly collect residue with reel mowers to accomplish this.

Research conducted by David Reed at Virginia Tech showed that the severity of clipping affects stem length at the time of transplanting. For example, severe clipping (0.5 inch above the bud) decreased stem length but did not increase stem diameter as compared to normal clipping (1.5 inches above the bud). Therefore, there is no advantage to severe clipping. Dr. Reed found that severe clipping early in the season was particularly detrimental, resulting in very short transplants that grew slowly in the field. Additional work in North Carolina indicated that severe clipping, down to the bud, immediately before transplanting reduced early season growth and delayed flowering.

Current recommendations are to begin clipping at three- to five-day intervals when total plant height is two to 2.5 inches above the tray and to set the blade height at one to 1.5 inches above the bud. This procedure provides the best balance of uniformity, stem length, and disease management.

5. MANAGING NUTRIENTS

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For the past 15 years, fertilizer prices have increased in cost per pound of material. While prices have declined from the record highs of 2008-2009, it is extremely likely that this reduction will be short lived. Figure 5-1 demonstrates both of these trends for selected nutrient sources from 2000 to 2013. At least one of the selected fertilizer sources is not used in tobacco production (potassium chloride, or 0-0-60); however, it is the overall price trend that is important, as it reflects price trends for tobacco grade sources of potassium as well.

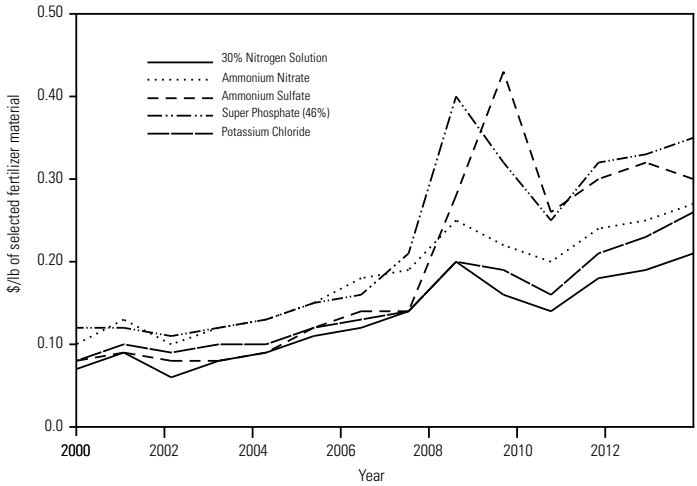

Figure 5-1. Average price per pound of selected fertilizer materials, 2000-2013. From R. Nehring, USDA-ERS.

Although the cost of fertilizing tobacco has increased significantly, the good news is that there is a wide range in the cost of fertilization programs, and some programs offer significant savings without sacrificing yield or quality. Research conducted in all tobacco producing areas of North Carolina has consistently shown that programs utilizing all-nitrate or UAN nitrogen products

produce tobacco leaf with similar yield and quality. The most recent studies conducted compared 32 percent UAN (25 percent nitrate, 75 percent ammonium), ammonium nitrate (50 percent nitrate, 50 percent ammonium), and calcium nitrate (100 percent nitrate) to supply all of the nitrogen to the crop. The study was conducted at research stations near Oxford and Kinston, North Carolina, in 2004, 2005, and 2006. Yield and quality were not affected by nitrogen source at any location during any year of the study. More recent studies conducted in 2016 and 2017 confirm these findings (Table 5-2) and demonstrate the usability of a wide range of nitrogen fertilizer sources.

The bottom line on ammonium versus nitrate is that under our growing conditions, nitrification is rapid enough that UAN products containing 75 percent of the nitrogen as ammonium are equally as acceptable as all-nitrate nitrogen sources (such as calcium nitrate). Growers should feel comfortable using any of these products and should base the decision on factors such as application technology and cost because crop response is not an issue.

A recent survey of county Extension agents found that nearly 50 percent of tobacco acreage received at least some of its nitrogen from liquid materials. Additionally, it is estimated that 20 to 25 percent of tobacco acreage receives all of its nitrogen from a liquid material on an annual basis. Consider the following practices to reduce fertilization costs:

- Use UAN products, such as 28, 30, or 32 percent, for at least the sidedress application if not the entire nitrogen program. See treatments 5, 6, and 7 in Table 5-1.
- Apply no more phosphorus than recommended from the soil test. More than 90 percent of the soil test reports from tobacco fields in the coastal plain and 50 percent from fields in the piedmont recommended not applying fertilizer phosphorus. Growers reluctant to not apply any phosphorus can apply 5 pounds of phosphorus in the transplant water, which has been shown to equal the growth response of 40 pounds of phosphorus banded in the complete fertilizer (Figure 5-2).
- Research in North Carolina also indicates that rates of applied potassium can be reduced to 75 pounds of K_2O per acre on soils that have a medium to high potassium index, fine to medium soil texture, and relatively shallow depth to clay (less than 10 inches) without reducing yield or quality. Potassium can also be broadcast-applied and incorporated prior to forming raised beds as much as 30 days before transplanting on soils with characteristics similar to those previously mentioned. This alternative approach to potassium fertility fits extremely well with production systems in which producers are only making independent applications of nitrogen and potassium.
- Based on current fertilizer prices, the most economical program involves the application of a potash material, such as potassium sulfate or potassium magnesium sulfate (or blend), to supply all of the potassium suggested by the soil test report and a UAN product to supply all of the nitrogen (Table 5-1). If soil phosphorus levels are high to very high, then no more than 5 pounds of phosphorus in the transplant water is sufficient to provide rapid early season growth.

It is likely that early broadcast applications of potassium with current rate recommendations would only be of concern with combinations of conditions that included coarse soil textures, low potassium indices, and/or excessive rainfall.

- Avoid products that add cost without improving profitability. For example, the product Avail has been shown—under conditions of limited soil phosphorus outside of the tobacco production region in North Carolina—to improve phosphorus uptake. However, phosphorus levels in most of our tobacco fields are very high. Studies conducted during 2008 showed no advantage of including Avail in the fertilizer for tobacco produced in fields with typical soil phosphorus levels (Table 5-3).

Table 5-1. Effect of fertilizer treatment on tobacco yield, value, and grade index at three North Carolina locations, 2005

	Onslow County			Upper Coastal Plain Research Station			Central Crops Research Station			Average		
Treatment	**Yield (lb/a)**	**Value ($/a)**	**Grade Index**	**Yield (lb/a)**	**Value ($/a)**	**Grade Index**	**Yield (lb/a)**	**Value ($/a)**	**Grade Index**	**Yield (lb/a)**	**Value ($/a)**	**Grade Index**
1. 6-6-18 667 lb/acre + 15.5-0-0 194 lb/a	2,799 a	3,191 a	75 a	2,031 a	2,963 a	91a	3,266 a	3,767 a	75 a	2,699	3,307	80
2. 6-3-18 667 lb/a + 15.5-0-0 194 lb/a	2,784 a	3,284 a	77 a	2,170 a	3,251 a	93a	3,256 a	3,521 a	70 a	2,737	3,352	80
3. 0-0-22 540 lb/a + CN-9 64 GPA	3,350 a	3,717 a	70 a	2,068 a	3,021 a	91a	3,249 a	4,019 a	79 a	2,889	3,585	80
4. 0-0-22 540 lb/a (broadcast) + CN-9 64 GPA	3,408 a	3,865 a	73 a	2,226 a	3,290 a	92a	3,142 ab	3,577 a	74 a	2,925	3,577	80
5. 0-0-30 400 lb/a + 30% UAN 21.5 GPA	3,241 a	3,507 a	68 a	1,966 a	2,717 a	86a	3,247 a	3,725 a	74 a	2,818	3,316	76
6. 0-0-30 400 lb/a + 30% UAN 21.5 GPA + 9-45-15 11 lb/a TPW	3,215 a	3,711 a	75 a	1,759 a	2,450 a	86a	3,166 a	3,980 a	79 a	2,713	3,380	80
7. 0-0-30 400 lb/a + 15.5-0-0 452 lb/a + 9-45-15 11 lb/a TPW	3,191 a	3,487 a	71 a	2,016 a	2,927 a	91a	3,118 ab	3,896 a	79 a	2,775	3,437	80
8. 6-3-18 667 lb/a + 15.5-0-0 194 lb/a + 9-45-15 11 lb/a TPW	3,466 a	4,066 a	74 a	1,869 a	2,741 a	91a	3,276 a	3,664 a	73 a	2,870	3,490	79
9. 6-6-18 667 lb/a + 15.5-0-0 194 lb/a + 9-45-15 11 lb/a TPW	3,000 a	3,389 a	74 a	1,732 a	2,486 a	89a	2,882 c	3,335 a	75 a	2,538	3,070	79
10. 12-4-17 500 lb/a + 13-44 76 lb/a	3,243 a	3,663 a	72 a	2,174 a	3,163 a	91a	2,982 bc	3,712 a	79 a	2,800	3,513	81

Treatment results followed by the same letter within a column should be considered similar.

Table 5-2. Effect of nitrogen fertilizer composition on tobacco yield, quality, price, value, and cured leaf chemistry. Data are pooled across four growing environments

Nitrate %	Ammonium %	Yield	Quality	Price	Value	Total Alkaloids	Reducing Sugars
100	0	2,967 a	79 a	1.64 a	4,782 a	2.68 a	15.56 a
50	50	2,881 a	76 a	1.54 a	4,341 a	2.79 a	15.75 a
25	75	2,838 a	74 a	1.49 a	4,218 a	2.69 a	16.50 a
0	100	2,724 a	73 a	1.47 a	4,032 a	2.69 a	16.38 a

Treatment results followed by the same letter within a column should be considered similar.

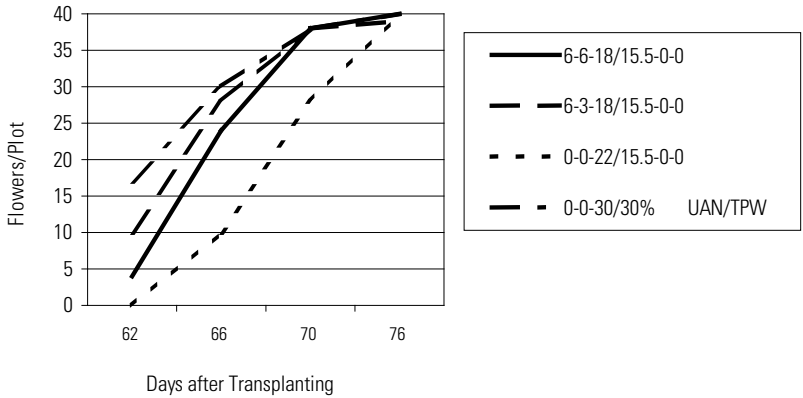

Figure 5-2. Effect of phosphorus application on flowering rate at the Upper Coastal Plain Research Station, 2005

Table 5-3. Effect of fertilizer treatment on tobacco yield, grade index, price, and value at two North Carolina locations, 2008

	Cunningham Research Station			Oxford Tobacco Research Station		
Treatment	Yield (lb/a)	Value ($/a)	Grade Index	Yield (lb/a)	Value ($/a)	Grade Index
6-6-18 667 lb/a + 15.5-0-0 226 lb/a	2,974 a	5,138 a	84 a	2,496 a	4,198 a	80 a
8-8-28 + Avail 500 lb/a + 15.5-0-0 226 lb/a	2,895 a	5,002 a	84 a	2,491 a	4,338 a	83 a

Treatment results followed by the same letter within a column should be considered similar.

SOIL TESTING

Have your soil tested. This is the first step in planning an economical and environmentally sound fertilization program. Testing is provided as a free service by the North Carolina Department of Agriculture and Consumer Services from April to November of each year. Each soil sample is analyzed to determine pH and the available levels of most major nutrients, such as phosphorus (P_2O_5), potassium (K_2O), calcium (Ca), magnesium (Mg), and sulfur (S). The analysis also determines soil levels of several micronutrients, such as manganese (Mn), copper (Cu), and zinc (Zn). The soil test report suggests application rates for lime and for each nutrient that should meet crop needs under good growing conditions.

The nutrient rates suggested on the soil test report reflect only what is found in the sample. Therefore, each sample should be taken properly so it adequately represents the field where the crop is to be grown. Soil sample reports from fields tended regularly by the same grower should be no more than two years old. For unfamiliar fields or those out of tobacco production for several years, take samples four to six months before the first tobacco crop. Submitting samples in the fall rather than winter or spring will enable you to receive soil test reports quickly and allow more time for planning fertilization programs. Soil boxes and instructions for taking samples can be obtained at your county Cooperative Extension center.

Liming and Soil pH

Provide the ideal pH of 5.8 to 6.2 through the application of dolomitic limestone. This is a key step in a cost-effective and responsible nutrient management plan. Low pH causes greater solubility of soil aluminum (and manganese in piedmont soils), which reduces root growth and development. Therefore, liming to promote healthy root systems improves drought tolerance and nutrient absorption, sometimes resulting in better yields. Alternatively, overliming and, therefore, increasing soil pH above 6.2 can reduce the availability of certain micronutrients, such as boron, iron, manganese, copper, and zinc. While these nutrients can be supplemented through N-P-K and/or specialty fertilizers, the most cost effective management program will promote micronutrient availability within the soil profile.

In research trials, limed plots produced higher yields than unlimed plots regardless of the nitrogen rate (Table 5-3). Also, note that the yield of unlimed plots that received 15 pounds per acre of extra nitrogen was no higher than that of limed plots that received 15 pounds per acre less than suggested nitrogen. These data indicate the following:

- Extra nitrogen cannot overcome the adverse effects of low soil pH.
- Lower nitrogen rates are possible when acid soils are limed according to soil test suggestions.

Table 5-4. Effects of lime and nitrogen on tobacco yield

Nitrogen Rate (lb/a)	Yield (lb/a)	
	No Lime Used	Lime Used
Suggested -15	2,272	2,497
Suggested	2,434	2,688
Suggested +15	2,405	2,516

Table 5-5. Effect of nitrogen rate on tobacco yield and value at the Lower Coastal Plain Experiment Station, 2004–2006

Nitrogen Rate (lb/a)	2004		2005		2006	
	Yield (lb/a)	Value ($/a)	Yield (lb/a)	Value ($/a)	Yield (lb/a)	Value ($/a)
0	2,232	4,381	2,513	3,500	1,971	2,880
20	2,590	4,543	2,773	3,800	2,056	3,005
40	2,825	4,935	2,939	4,086	2,063	2,998
60	3,002	5,288	3,027	4,247	2,033	2,855
80	3,051	5,357	3,009	4,183	2,053	2,928
100	—	—	2,799	3,866	2,029	2,774
120	—	—	2,893	3,923	2,012	2,701

Quick Reference Guide to Fertilization

1. Have a soil sample tested to determine nutrient and lime needs. Use dolomitic lime, if needed, to adjust pH and supply magnesium as well as calcium. Do not overlime!
2. Use a base nitrogen rate of 50 to 80 pounds per acre. Your portion of the rate range will depend on topsoil depth and texture, previous crop grown, and personal experience (Table 5-4).
3. Apply 20 to 30 pounds of sulfur per acre on deep, sandy soils. Sulfur application recommendations are now provided in soil test reports. Read the label to be sure that the complete (N-P-K) fertilizer contains sulfur. If the complete fertilizer does not provide this nutrient, then apply a sidedresser containing sulfur.
4. Determine and make leaching adjustments for nitrogen losses with caution, only after leaching occurs. Do not assume that leaching will occur and apply extra nitrogen up front in the growing season.
5. Use a method of fertilizer application that maximizes nutrient uptake efficiency but minimizes fertilizer salts injury and early season leaching losses. Examples include the bands at transplanting and bands within 10 days after transplanting methods. The latter method is more risky than the first on poorly drained soils because frequent rains after transplanting could delay fertilizer application for more than 10 days. Fertilizers should be

incorporated into the soil to reduce nutrient losses through runoff and/or volatility. Liquid nitrogen materials can be injected through a sidedress application or applied to the side(s) of the bed and incorporated with cultivation.

IN-SEASON ADJUSTMENTS

Adjustments for Leaching

Leaching occurs when certain nutrients move below normal rooting depth due to excessive water moving (percolating) through the root zone of deep, sandy soils. Leaching of nitrogen is more likely to reduce yield and quality than leaching of other nutrients. Although leaching losses of sulfur, magnesium, and potassium sometimes occur, their effects on yield and quality are relatively small.

More than 50 to 80 pounds of nitrogen per acre may be needed if leaching occurs, but determining the correct amount to replace is one of the most difficult and risky tasks in tobacco production. A general guide to leaching adjustments for nitrogen is shown in Table 5-5. The amount of nitrogen to replace is expressed as a percentage of the suggested base rate that was applied before leaching occurred. If you used excess nitrogen before leaching occurred, subtract the number of excess pounds from the number of replacement pounds calculated. This guide is based on three major factors that influence the amount of leaching:

- *Topsoil depth to clay*. Topsoil depth is used in the guide because water usually moves more freely and in larger quantities through deeper topsoil. The mass of tobacco roots normally occurs in the upper 12 to 14 inches of soil. Therefore, the deeper the clay below rooting depth, the more likely it is that nitrogen will leach below the root mass.
- *Age of the crop when leaching occurs*. Crop age is included in the guide because plants absorb more of the needed nutrients as they get older, and the amounts left in the soil and subject to leaching decrease as the crop grows. Also, as the plants get larger, their leaves form a canopy that sheds some of the water to the row middles, reducing the amount of water passing through the fertilized zone.
- *Estimated amount of water (in inches) that moves through the root zone*. A reasonable estimate of the amount of water that enters the soil and ultimately percolates through the root zone is necessary to calculate the leaching adjustment. The amount of rainfall alone usually is not a good indication of how much leaching has occurred. Factors such as soil texture and slope, crust formation, duration of rainfall, and the amount of moisture already in the soil also are important.

Unfortunately, a practical method that includes these many percolation factors has not been developed, but growers who have experienced similar rainfall on their land in past years can make reasonable estimates. An invaluable tool in making leaching adjustments is an up-to-date record of daily rains and estimates of how much of each rain soaked into the soil.

Table 5-6. Nitrogen adjustments for leaching

Topsoil Depth	Estimated Water Percolated through Soil	Percentage of Applied Nitrogen to Replace after Transplanting[a]		
		1–3 Weeks	4–5 Weeks	6–7 Weeks
Less than 10 inches to clay	1 inch	0	0	0
	2 inches	20	10	0
	3 or more inches	30	20	0
10 to 16 inches to clay	1 inch	30	20	0
	2 inches	45	30	10
	3 or more inches	60	40	15
17 or more inches to clay	1 inch	50	25	15
	2 inches	75	35	20
	3 or more inches	100	45	25

[a] Apply about one pound of potassium (K_2O) for each pound of nitrogen used as a leaching adjustment if the topsoil is deeper than 10 inches.

Because phosphorus leaches very little in our soils, it is both expensive and unnecessary to use phosphorus-containing fertilizers, such as 6-6-18, to make leaching adjustments. Some growers do this, however, to supply additional sulfur (S), magnesium (Mg), or both, along with nitrogen, for adjustments on deep, sandy soils. These nutrients can be supplied at less cost and just as effectively by using 13-0-14 or an 8-0-24 that guarantees sulfur and magnesium but contains no phosphorus. Another alternative is to mix equal amounts of Sul-Po-Mag (K-Mag) and one of the 1:0:0 ratio sidedressers. For example, an equal mixture of 15.5-0-0 fertilizer and Sul-Po-Mag gives an 8-0-11 N-P-K analysis, which also provides 5 percent magnesium and 11 percent sulfur. (If additional nitrogen is not needed, about 100 to 150 pounds of Sul-Po-Mag per acre usually will supply adequate sulfur and magnesium.)

Adjustments for Drowned and Partially Drowned Tobacco

Distinguishing between drowning and leaching is often confusing because excess water causes both problems. Leaching is usually not a serious problem on soils that have clay within 10 to 12 inches of the surface because percolation through the root zone is restricted. If the soil becomes saturated, oxygen starvation and then root decay will begin unless the saturated condition is alleviated within about 24 hours. Usually, the plants yellow and partially or completely wilt. Wilting is a symptom of drowning and indicates that leaching losses are minimal because water remains in the root zone rather than moving through it. Although some nitrogen may be moved down to the clay, causing a temporary deficiency, it will be absorbed later as root growth resumes.

In most drowning situations, adding 10 to 15 pounds of extra nitrogen usually benefits the crop if it was not overfertilized with nitrogen before drowning. However, using the leaching adjustment procedure for a drowned crop often overestimates the amount of nitrogen to replace and may delay ripening and cause curing problems later in the season.

Heavy, frequent rains may cause drowning (root injury). Deep rooting is limited as long as the soil remains saturated, confining root development to the upper 6 to 10 inches. Many growers make at least one application of dry or liquid fertilizer after drowning in an attempt to reduce losses in yield and quality. Experiments were conducted on research stations near Kinston and Clayton in 1995 to study the effects of soil-applied fertilizers on the yield and quality of partially drowned tobacco. (The term "partially drowned" is used because the tobacco remained wilted for only several days and then recovered.) The fertilizers used are shown in Table 5-7; the results are averages of two nitrogen rates at Kinston (15 and 30 pounds per acre) and one nitrogen rate at Clayton (20 pounds per acre). All fertilizer treatments, made in one application on June 20, improved yield and value per acre compared to the nonfertilized control. The 16-0-0 and 30 percent liquid nitrogen fertilizers increased yield and value about 10 percent, and the 15-0-14 and 8-0-11 fertilizers increased yield and value about 15 percent. This indicates that the potassium supplied by the 15-0-14 and 8-0-11 fertilizers may have improved yield more than the 16-0-0 and 30 percent liquid nitrogen fertilizers that supplied only nitrogen. None of the fertilizers improved grade index or average market price compared to the control.

Table 5-7. Effects of fertilizer additions on yield and value of partially drowned tobacco, 1995[a]

Fertilizer Treatment[a]	Application Method	Yield (lb/a)	Grade Index	Price ($/cwt)	Value ($/a)
None	—	1,714	77	173.50	2,974
16-0-0	BC-OT	1,887	77	174.60	3,294
30% nitrogen	WB-RM	1,873	79	175.50	3,288
15-0-14	BC-OT	1,961	76	173.80	3,408
8-0-11	BC-OT	1,996	77	174.50	3,483

[a] Average results of tests conducted at research stations near Clayton and Kinston. N rates for each fertilizer were 15 and 30 lb/acre at Kinston and 20 lb/acre at Clayton. Adjustments were applied on 6/20/95. BC-OT = broadcast overtop of plants; WB-RM = wide band sprayed in row middle.

The results in Table 5-8 indicate that using fertilizers at rates to provide 30 pounds of nitrogen per acre was no more effective than using them at rates to provide 15 pounds of nitrogen per acre. In addition, the nitrogen rate did not affect grade index or average market price. The plant roots in these tests never recovered from the water injury. Therefore, the crops did not respond fully to the applied nutrients. Unfortunately, the results of these tests indicate that much of the extra fertilizer applied to drowned crops does not benefit them. Observations on farms in 1995 indicated that the more severe the drowning (root injury), the less likely the crops were to recover, regardless of the kinds or rates of fertilizers used.

Table 5-8. Effects of nitrogen rate adjustments on yield and value of partially drowned tobacco, 1995

Nitrogen Adjustment (lb/a)	Yield (lb/a)	Grade Index	Price ($/cwt)	Value ($/a)
0	1,748	74	180.00	3,146
15[a]	1,946	74	179.30	3,489
30[a]	1,903	76	179.30	3,412

[a]Results averaged over 16-0-0, 30 percent liquid N, 15-0-14, and 8-0-11 fertilizers for each N rate. Test conducted at Lower Coastal Plain Research Station near Kinston.

TIME AND METHOD OF FERTILIZER APPLICATION

Proper placement and timing of fertilizer applications provide maximum return for each dollar spent on fertilizers. Fertilizers should be applied at the proper time and with the proper method to maximize nutrient use by the crop while minimizing leaching losses and fertilizer salts injury to roots. Four methods of fertilizer application have been evaluated in on-farm tests under a wide range of soil and climatic conditions. Results varied among locations, primarily because of differences in soil moisture at and following transplanting:

- If soil moisture was adequate but not excessive, the *bands at transplanting* and *bands within 10 days after transplanting* methods yielded moderately better than the broadcast or one band deep methods.
- If early leaching conditions occurred, best results were obtained with the *bands within 10 days after transplanting* method, with *bands at transplanting* being a close second, and the *broadcast* method giving the poorest results.
- When the soil was dry, which contributed to fertilizer injury, the *bands within 10 days after transplanting* method gave the best results, and the *one band deep* method the poorest results.
- Overall, the *bands at transplanting* and *bands within 10 days after transplanting* methods produced better yields more consistently than the *broadcast* and *one band deep* methods. These methods are also more environmentally sound than pre-transplanting methods because nutrient uptake is more efficient and leaching losses are reduced.

UNDERSTANDING THE NUTRITIONAL NEEDS OF THE PLANT

Primary Nutrients

Nitrogen (N). Nitrogen has a greater effect on tobacco yield and quality than any other nutrient. Too little nitrogen reduces yield and results in pale, slick cured leaf. Too much nitrogen may increase yield slightly but may also make mechanical harvesting and curing more difficult, delay maturity, extend curing time, and result in more unripe cured leaf. Excessive

nitrogen also stimulates sucker growth, which can lead to excessive use of maleic hydrazide (MH) and increase problems with hornworms and aphids. Nitrogen is also very leachable, and overapplication may contribute to groundwater contamination in deep, sandy soils.

Soil analysis is not used to estimate the nitrogen rate needed for a specific tobacco field in North Carolina. Rather, the 50- to 80-pound-per-acre range shown on the soil test report is based on information from numerous field tests conducted across the state. In these tests, a base nitrogen rate of 50 to 80 pounds per acre has given consistently good results on most soils in most seasons. This is the total amount of nitrogen supplied by normal applications of the N-P-K fertilizer and the sidedresser but does not include additional nitrogen sometimes needed for leaching adjustments. The lower portion of the range is suggested for fine-textured, fertile soils, especially where legumes such as soybeans or peanuts were grown the previous year. The higher portion of the range is suggested for coarse-textured soils with topsoils deeper than 15 inches to clay.

Suggested nitrogen rates for several average topsoil depths are shown in Table 5-9. Determine your portion of the nitrogen rate range primarily by topsoil depth, or depth to clay. Fields with deeper, sandier topsoils usually are more leachable and contain less nitrogen as humic matter than those with shallower, more heavily textured topsoils. Generally, you should reduce the nitrogen rates shown by about 5 to 10 pounds per acre if the previous crop was a legume or the variety to be planted is known to mature late or cure poorly when overfertilized with nitrogen. Even greater nitrogen rate reductions may be needed on dark soils with 1 percent or more humic matter.

Table 5-9. Base nitrogen rates for tobacco in relation to topsoil depth

Topsoil Depth (inches)	Nitrogen Rate[a] (lb/a)
5	50
10	60
15	70
20+	80

[a] Does not include leaching adjustments.

Also, when tobacco follows a heavily fertilized but poor corn crop (less than 75 bushels per acre), the residual nitrogen available for the tobacco may be as high as that left by soybeans or peanuts.

Only 15 pounds of extra nitrogen may reduce leaf quality, particularly in dry seasons. Both drought and excess nitrogen delay maturity and increase the amount of unripe tobacco. The first step to increasing the amount of ripe tobacco is to use a reasonable base nitrogen rate (particularly if irrigation is not available and mechanical harvesting is used), depending on topsoil depth, previous crop, variety to be grown, and experience. Also, be cautious and conservative with leaching adjustments for nitrogen. The second step is to delay harvest, if

necessary, and make three or more primings so that each priming will have a high percentage of ripe leaves. The rate of ripening depends primarily on the amount and distribution of water, the nitrogen rate, soil type, and variety, so base your harvest rate on these factors, not on the calendar date or how fast your neighbor's tobacco is being harvested.

The normal ripening process is caused by partial nitrogen starvation, which should begin about topping time. Therefore, nitrogen in the soil should be nearly depleted by flowering. Overapplication of nitrogen, prolonged drought, or both extend nitrogen uptake beyond topping time and therefore delay ripening because the crop is still absorbing nitrogen. Leaves harvested when they are high in nitrogen are more difficult to cure and often turn dark at the end of yellowing and into the early leaf-drying stage. This problem is increased by dry, hot conditions, which cause the leaves to appear riper than they really are.

Phosphorus ($P_2 0_5$) and potassium ($K_2 0$). Phosphorus is not very leachable, even in sandy soils, and a good tobacco crop only removes about 15 pounds per acre (as $P_2 0_5$). However, many times this amount has been applied to tobacco fields over the years, resulting in at least "high" levels of available phosphorus in about 85 percent of the fields used for tobacco. Under this soil condition, no more than 5 pounds of phosphorus in the transplant water is sufficient to promote early season growth, specifically when cool, damp soil conditions are present just after transplanting. Applying a reduced rate of phosphorus in the transplant water greatly increases phosphorus use efficiency while reducing the risk of runoff into nearby bodies of water. In addition, phosphorus continues to be one of the more expensive nutrients required for crop production in general (Figure 5-1); therefore, reduced application rates for tobacco production will also reduce the cost of a desired fertility program. Potassium is leachable, especially in deep, sandy soils, and a good crop removes about 90 pounds per acre (as $K_2 0$). However, about 60 percent of our tobacco soils contain at least "high" levels of available potassium because of more abundant soil sources and excessive application. Also, subsoils in tobacco fields often contain substantial amounts of potassium and other leachable nutrients that are seldom measured by soil tests because only topsoils are usually sampled (Table 5-10). These results represent primarily coastal plain soils and should be considered as preliminary at this point. But they do provide additional evidence that application of several leachable nutrients above soil test recommendations usually does not improve tobacco yield and quality, but does increase production costs. In addition, overapplication increases the potential for these nutrients to reach our ponds and streams by soil and water movement.

Table 5-10. Average soil test levels of several nutrients in topsoils and subsoils of 19 flue-cured tobacco fields, 1999–2016

	Soil Nutrients				
	(Availability Index)[a]			(% of CEC)	
Soil Horizon	**P**	**K**	**S**	**Ca**	**Mg**
Topsoil	86	60	72	52	22
Subsoil	33	56	130	52	26

[a] 0–10 = very low; 11–25 = low; 26–50 = medium; 51–100 = high; 100+ = very high.

Potassium has long been overapplied due to relatively low material cost and the demand the tobacco plant has for the nutrient. However, it is likely that producers can reduce total potassium input by as much as 10 to 20 percent without reducing leaf yield or quality. Recent research efforts focused on potassium nutrition indicate that as little as 75 pounds of K_2O per acre is sufficient for soils with medium to high potassium indices, medium to fine texture, and less than 10 inches to clay (Table 5-11). Additionally, leaf yield and quality were not reduced when potassium was not applied due to sufficient soil reserves and suitable growing conditions. In this situation, producers should still apply a minimum of 75 pounds K_2O per acre to prevent nutrient depletion within the soil profile.

Table 5-11. Tobacco yield and quality response to increasing rates of applied potassium[a,b]

Rate[c]	Yield	
lbs K_2O/acre	**lbs/acre**	**Quality**
0	2,740 a	81 a
75	3,072 a	83 a
100	3,035 a	82 a
125	2,970 a	81 a
150	3,035 a	81 a
175	2,986 a	81 a
200	3,028 a	81 a
225	3,087 a	79 a

[a] Treatment means followed by the same letter are not significantly different
[b] Study conducted in four North Carolina locations from 2009 to 2010
[c] K-Mag (0-0-22) potassium source

Specific soil conditions of medium to high potassium indices and shallow topsoil might be more common in the Piedmont than the Coastal Plain region of the state; however, the overall message is still valid: potassium rates can be reduced without having a negative impact on crop growth/ development. In areas marked by deep, sandy soil types, a split application of potassium (½ the full rate before or just after transplanting and ½ the full rate at layby) can mitigate some of the risk associated with excessive rainfall and nutrient loss.

Secondary Nutrients

The secondary nutrients of concern for tobacco are calcium (Ca), magnesium (Mg), and sulfur (S). These nutrients are called secondary because they are usually needed by most crops in smaller amounts than the primary nutrients. However, they must be available in adequate amounts for good yields and quality.

Calcium and magnesium (dolomitic lime). If soil pH is kept within the desirable range of 5.8 to 6.2 with dolomitic limestone, the available levels of calcium and magnesium will usually be high enough to meet the needs of the crop. Otherwise, 40 to 50 pounds of calcium (Ca) and 15 to 20 pounds of magnesium (Mg) per acre are needed from the N-P-K fertilizer. Even with proper liming, some magnesium deficiency may occur on deep, sandy soils (more than 15 inches to clay) under severe leaching conditions. In these instances, supplying 15 to 20 pounds of magnesium per acre in the fertilizer may be desirable in the second and third seasons after lime application. However, using N-P-K fertilizers containing calcium and magnesium will not substitute for using dolomitic lime if soil pH is too low. Be especially aware of low soil pH. The state's latest soil test summaries show that just over 25 percent of the tobacco fields tested in the last several years have had a pH lower than 5.5, with piedmont soils generally being more acidic than those in the coastal plain. If sulfate of potash magnesium (0-0-22) is used as the single potassium source, then Mg should be sufficient.

Calcium deficiencies are sometimes observed in North Carolina across a wide range of soil types and growing conditions, although they are more common during periods of rapid plant growth and are more typically observed near topping. Calcium is not mobile within the plant, and as a result, deficiency will be observed in younger leaves. Producers should be aware that Ca deficiencies are transient and will often disappear after topping occurs. When topping occurs, most of the affected tissue is removed from the plant. Furthermore, topping stimulates additional root growth, which can promote additional Ca uptake from the soil. Research in North Carolina has demonstrated that applications of Ca beyond what is applied through liming materials will not improve Ca uptake by the plant; therefore, foliar applications of Ca are not recommended during the season. In a study conducted during the 2015 growing season, liquid Ca was applied through foliar applications at rates supplying as much as 50 pounds Ca per acre. In this study leaf yield was not increased with the addition of Ca. Furthermore, severe leaf injury was observed where Ca was applied due to high salt content within the solution.

Sulfur (S). Sulfur deficiencies are most likely in deep, sandy soils (more than 15 inches to clay) that are low in humic matter (less than 0.5 percent). Because sulfur leaches, deficiencies are more likely in these soils following heavy rainfall in the winter and spring, especially if sulfur is omitted from the fertilizer of the next tobacco crop.

Symptoms of sulfur deficiency are very similar to (and are often mistaken for) symptoms of nitrogen deficiency. When a plant is low in nitrogen, the lower leaves are paler than the upper leaves and "burn up" prematurely. However, sulfur deficiency begins as yellowing in the buds; the leaves gradually pale from top to bottom, and the lower leaves do not "burn up" prematurely

unless nitrogen is also deficient. Because sulfur is required for nitrogen use in the plant, adding high rates of nitrogen to sulfur-deficient crops will not turn the crops green, and can, in fact, reduce leaf quality. Therefore, accurate diagnosis of the deficiency is very important and often requires tissue analysis.

Soil tests for sulfur are sometimes unreliable. Therefore, to reduce the chance of sulfur deficiency on deep, sandy soils, add 20 to 30 pounds of sulfur (S) per acre from the N-P-K fertilizer every year. Sulfur deficiency occurring before layby can be corrected by banding 100 to 150 pounds of Sul-Po-Mag or potassium sulfate (0-0-50) as soon as possible after the deficiency is identified. However, sulfur deficiency on soils less than about 12 inches to clay is often temporary, even when no extra sulfur is applied, because adequate sulfur is usually contained in subsoils (Table 5-10) and will be absorbed as roots reach this depth.

Micronutrients

The soil test report for tobacco shows a $ symbol in the "Suggested Treatment" block for copper (Cu) and zinc (Zn), and a $pH symbol for manganese (Mn), if the availability index for one of these micronutrients is low. The $ symbol indicates that corrective treatment may be beneficial, but it is uncertain that tobacco will respond to application of copper or zinc. The $pH symbol appears on the report when soil pH is greater than 6.1 and the manganese availability index is less than 26 (low or very low). The symbols also call attention to an enclosed note, also identified by a $ symbol, that provides information on suggested rates, sources, and application methods for these three micronutrients.

Crops differ in their response to micronutrients, and tobacco is considered less sensitive to low soil levels than other crops, such as corn, soybeans, and small grains. Micronutrients are also somewhat expensive, depending on the kind and source. Therefore, their application for tobacco is not likely to be beneficial unless indicated by soil or tissue analyses. When in doubt, use tissue analysis or strip testing on several rows to confirm a micronutrient need.

Copper (Cu) and zinc (Zn). Known deficiencies of copper or zinc are extremely rare for tobacco. Rates suggested on the soil test report will be sufficient for several years, and future test results should be used to determine if and when copper and zinc should be reapplied.

Manganese (Mn). Manganese deficiency begins to show on the lower leaves as flecks very similar to those caused by high ozone concentrations in the air (commonly called weather fleck). While weather fleck can occur anywhere in the state, manganese deficiency occurs primarily on low-manganese, overlimed soils in the coastal plain. Using too much lime causes soil pH to increase, which reduces manganese availability to plant roots. Tobacco plants that develop manganese deficiency are grown on soils with a pH of 6.2 or higher and low levels of soil manganese (availability index less than 26). Based on recent soil test results, 7 percent of the tobacco soils in the coastal plain were pH 6.5 or above. Therefore, tobacco planted in these soils is at risk for manganese deficiency, particularly on soil types such as Goldsboro, which have slightly higher organic matter than other coastal plains soils. Tobacco performs well when soil

pH stays in the 5.8 to 6.2 range. Other major crops, such as soybeans, corn, and small grains, also perform well in this pH range if soil phosphorus is high. Therefore, when these crops are in rotation with tobacco, they usually should not be limed at rates higher than those suggested by the soil test for tobacco.

Tissue analysis of flecked leaves, along with a soil test, is the best way to distinguish between manganese deficiency and weather fleck. However, it is important to submit leaf and soil samples as soon as flecking occurs because several days are required to complete analyses. If the problem is manganese deficiency, a corrective treatment should be made as soon as possible. If weather fleck is the culprit, only cooler, drier weather will help.

Manganese deficiency can be corrected by soil or foliar application of several manganese sources. Manganese sulfate is a relatively soluble, inexpensive source that can be used for soil or foliar treatment. The more expensive chelated sources generally perform satisfactorily as foliar sprays but are not superior to sulfates when applied to the soil. For soil applications, mixing the manganese source with acid-forming fertilizers increases its effectiveness, and banding is usually better than broadcasting. Do not broadcast manganese on soils with a pH greater than 6.1 because it will be converted to a less available form. For band application, special blends may be required because premium fertilizers usually do not contain enough manganese to correct a deficiency. When applying manganese, the general recommendation for actual Mn in North Carolina is to add about three pounds per acre banded, 10 pounds per acre broadcast, or 0.5 pound per acre as a foliar spray. Foliar application of manganese is an efficient way of correcting an unexpected deficiency because lower rates are often as effective as much higher rates of soil-applied manganese.

Chloride (Cl). There is no suitable soil test for chloride, but this nutrient is included in most N-P-K tobacco fertilizers. You will apply sufficient chloride when you use N-P-K fertilizers guaranteeing chloride at rates suggested in Table 5-9. Suggested rates of most fumigants also supply adequate amounts of chloride as chlorine; when Telone C-17 or Chlor-O-Pic is used, the N-P-K fertilizer does not need to contain chloride. Otherwise, the fertilizer should include enough chloride to provide a maximum of 20 to 30 pounds per acre. Higher rates will not improve yield but can reduce quality. Chloride may not be included in some fertilizers, particularly blends or liquids, unless requested by the grower.

Recent studies in North Carolina confirm some of these statements. Chloride application rates ranging from 0 to 100 lbs per acre were evaluated in 2016 and 2017. Cured leaf yield and value were not affected; however, cured leaf quality was reduced when more than 50 to 60 pounds of Cl^- was applied. More concerning was the fact that Cl^- concentration in cured leaves exceeded 1%, which has been designated as the threshold for poor smoke flavor and aroma, in treatments receiving more than 30 pounds Cl^- per acre. Due to issues associated with reduced quality and the potential impacts to smoke sensory, producers are encouraged to apply no more than 20 to 30 pounds of the nutrient per acre. The classic Cl toxicity symptoms associated with excess Cl (dark, brittle leaves that curl upward) were not observed in these studies, thus indicating that

visual estimates of Cl^- exposure may not always be reliable and that tissue sampling should be utilized for diagnosis.

Boron. Deficiencies of boron (B) have been documented in North Carolina. There are a number of factors, such as rainfall, soil type, and choice of fertilizer program, that likely contribute to deficiency. Producers should be aware that the range of B deficiency and toxicity is very narrow and that the deficiency should be confirmed prior to B application. Research has demonstrated a positive response in deficient plants receiving 0.5 pounds of elemental B per acre in a foliar application of the nutrient. Alternatively, B toxicity has occurred when foliar application rates are increased to 1.0 pound of elemental B per acre. Producers should contact their local Extension agent if a suspected deficiency is observed and should exercise extreme caution when making supplemental applications.

Excessive rates or improper application of some micronutrients can cause toxicity. Contact your county Extension agent if you suspect you had a micronutrient problem in 2019 or if your soil test indicates that a problem might occur in 2020. Your agent can help you decide whether treatment is advisable and, if so, which sources, rates, and application methods are most effective.

NUTRIENT DIAGNOSTIC KEYS

Thanks to funding from the North Carolina Tobacco Foundation, an online tobacco nutrient diagnostic key has been developed for producers and allied industry. The diagnostic key can be used to identify nutritional disorders and corrective measures. The diagnostic key can be found on the homepage of the NC State University Tobacco Portal (tobacco.ces.ncsu.edu) or by visiting https://diagnosis.ces.ncsu.edu/tobacco/. An electronic iBook has also been developed for producers and is available free of charge for iPod, iPad, and iPhone users. Search for "Tobacco: Diagnosing Nutritional Disorders" in the book section of the iTunes store. Once downloaded, the iBook will be saved to the specific device and can be used offline.

LOWER LEAF REMOVAL PROGRAMS

Recently, producers have been encouraged to exclude the lowermost leaves (lugs) from harvest. Previous research has suggested that the removal of four or eight leaves per plant can significantly reduce yield and value. Interest has been expressed regarding nitrogen (N) application after leaf removal, and whether or not the practice could further promote upper-stalk leaf development. In four environments across North Carolina, three leaf removal programs (zero, four, and eight leaves per plant) were coupled with four N application rates (0, 5, 10, and 15 lbs per acre). At each location, base nitrogen application rates were applied using conventional practices, lower leaves were removed at topping, and additional N was applied to the soil surface immediately following leaf removal. Results indicate that yield is reduced as leaf removal number increases and that subsequent N application does not induce upper-stalk compensation to a level that achieves a yield comparable to scenarios without leaf removal (Table 5-12). However, in these studies, the percentage of lug grades was reduced in the four

leaf removal program and nearly eliminated in the eight leaf removal program. Nitrogen did generally improve leaf price per pound and value, which may have been a result of slight N losses from excessive early season rainfall and resulting N starvation. Lastly, N application after leaf removal did not result in significant leaf greening; however, this practice should be used with caution as environmental conditions following late-season N application sometimes delay ripening and inhibit harvest.

Table 5-12. The effect of lower leaf removal number and nitrogen application rate to tobacco yield, quality, price, value, and crop throw

Treatment	Yield		Price	Value			
Leaf Removal	**lbs/acre**	**Quality**	**$/lb**	**$/acre**	**%X**	**%C**	**%B**
0 leaves/plant	2,702 a	75 a	1.54 a	4,102 a	30 a	26 a	44 c
4 leaves/plant	2,187 b	75 a	1.58 a	3,450 b	14 b	27 a	59 b
8 leaves/plant	1,866 c	75 a	1.62 a	3,031 b	2 c	12 b	86 a
N Application							
0 lbs/acre	2,194 a	74 a	1.55 b	3,417 b	17 a	21 a	62 a
5 lbs/acre	2,240 a	75 a	1.59 ab	3,494 b	16 a	21 a	63 a
10 lbs/acre	2,274 a	75 a	1.57 ab	3,491 b	16 a	21 a	63 a
15 lbs/acre	2,297 a	77 a	1.62 a	3,708 a	12 a	25 a	63 a

Treatment results followed by the same letter within a column and main effect (leaf removal or N application) should be considered similar.

6. MANAGING WEEDS

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Effective weed management is necessary for profitable tobacco production. If left uncontrolled, weeds can reduce yield, increase chance for disease, and interfere with management practices including harvest. Furthermore, weed seed and debris can contaminate cured leaf, decreasing quality and overall crop price. A sound weed management plan in tobacco consists of crop rotation, cultivation, early stalk and root destruction, hand-weeding, and chemical control. A healthy, rapidly growing plant can aid with weed control by competing for sunlight and nutrients.

WEED MONITORING

Tobacco production is very "hands on" and in-season weed monitoring can be done without additional trips to the field. Proper weed identification is needed because weeds vary in response to herbicides (Table 6-1). Periodic in-season weed monitoring will be helpful in preventing weed infestations from occurring, especially with species such as Palmer amaranth. Keeping accurate field records of the species and population of weeds will help with future weed management plans, regardless of crop.

Herbicide resistant weeds in tobacco production are not as serious of an issue as in other crops. This is due to the intense management practices and lack of herbicide use (little selection pressure exerted) compared to most other major row crops. However, this should not be a reason to relax weed management efforts. The loss of an herbicide labeled for tobacco production would be detrimental.

DEEP TILLAGE

Deep tillage with a bottom plow (moldboard plow) has been used in the production of agronomic crops, such as cotton, peanut, and soybean, to reduce the population of select weed species (primarily Palmer amaranth). In these systems, deep tillage (>12-15 inches) can bury weed seed at a depth within the soil profile that germination is not possible. When left undisturbed, weed populations can be reduced for multiple years within the same field. This practice works extremely well in cropping systems that do not use high, wide beds for planting or aggressive secondary cultivation.

In a North Carolina study conducted from 2012 to 2015, it was consistently demonstrated that deep tillage during field preparation reduced Palmer amaranth populations two weeks after transplanting when compared to shallow tillage (tillage depth ≤4 inches). However, this effect was not observed at layby (six weeks after transplanting) as both tillage systems had equal populations of the weed. It is believed that bedding and repeated post-transplanting cultivation ultimately re-exposed Palmer seed to the germination zone of the soil profile. Despite no change in long-term weed density between the two tillage systems, deep tillage did increase tobacco yield at one field site, a result that is credited to a reduction in soil resistance/compaction.

Where producers are using an injection shank for in-row fumigant application or a ripping shank when bedding, soil resistance and/or compaction are likely to be minimal—i.e., in-row ripping shanks can replace a bottom plow if the goal is to reduce soil resistance/compaction. Producers should note that if soils are excessively moist during tillage activities, the benefits of these practices to soil resistance are not likely to be observed. Finally, if producers are considering deep tillage, this method should be applied to soil types and landscapes that are not prone to erosion. Soil conservation plans must also be considered.

CULTIVATION

Herbicides can reduce the number of cultivations needed to produce a profitable, high-quality crop. However, properly timed cultivations are still an important weed and crop management tool.

Cultivation helps manage weeds not controlled effectively by herbicides. It also can improve weed control by soil surface–applied herbicides, such as Command and Spartan Charge, in the absence of an activating rainfall. However, excessive and deep cultivation can decrease the effectiveness of surface-applied herbicides by removing them from row-middles. Extend weed control with these herbicides by limiting deep cultivation to layby time.

Cultivation is also a good crop management tool. For example, building a high row ridge improves drainage, which aids disease management and decreases drowning. Cultivation also improves aeration and water penetration by decreasing crusting. However, excessive cultivation increases leaching of potassium and nitrogen, injures root systems, increases leaf scald in hot weather, spreads tobacco mosaic virus, and contributes to soil erosion.

Table 6-1. Expected weed control from herbicides labeled for use in tobacco

Weeds	Command	Devrinol	Poast	Prowl	Spartan Charge	Tillam	Aim
Barnyardgrass	E	GE	E	GE	F	GE	N
Bermudagrass	PF	P	FG	P	P	P	N
Broadleaf signalgrass	E	G	E	G	F	P	N
Crabgrass	E	E	GE	E	F	E	N
Crowfootgrass	E	E	FG	E	F	E	N
Fall panicum	E	G	E	GE	—	G	N
Foxtails	E	E	E	E	F	E	N
Goosegrass	E	E	GE	E	F	G	N
Johnsongrass (seedlings)	G	F	E	G	—	G	N
Sandbur	G	—	FG	G	—	G	P
Texas panicum	G	—	E	G	F	P	N
Nutsedge	P	P	N	P	E	FG	N
Cocklebur	F	P	N	P	FG	P	G
Common purslane	FG	E	N	P	G	G	G
Hairy galinsoga	G	PF	N	P	G	P	P
Jimsonweed	G	P	N	P	—	P	G
Lambsquarters	G	G	N	G	E	G	G
Morningglory	P	P	N	P	E	P	E
Pigweed	P	G	N	G	E	G	E
Prickly sida	E	P	N	P	G	P	P
Ragweed, common	G	F	N	P	P	P	N
Ragweed, giant	PF	PF	N	P	—	P	N
Sicklepod	P	P	N	P	P	P	P
Smartweed	G	P	N	P	E	P	G

Note: Ratings are based on average to good soil and weather conditions for herbicide performance and on proper application rate, technique, and timing.
E = Excellent control, 90% or better.
G = Good control, 80%–90%.
F = Fair control, 60%–80%.
P = Poor control, 1%–59%.
N = No control.

PROBLEM WEEDS

Nutsedge

High populations of yellow nutsedge, purple nutsedge, or both are often a problem in tobacco fields. Yellow nutsedge occurs throughout North Carolina, and purple nutsedge is normally found in eastern and southeastern counties. Purple nutsedge has a reddish-purple to brown seedhead, and its bitter-tasting tubers occur in chains connected by rhizomes. Yellow nutsedge has a yellow

seedhead with single, sweet-tasting tubers on each rhizome. Purple nutsedge is more difficult to control than yellow nutsedge.

Spartan Charge and Tillam are both labeled for nutsedge control. Spartan Charge provides excellent control of both nutsedge species (although slightly better control of yellow than purple), and Tillam provides good control (Table 6-1). Studies have found that labeled and below-labeled rates of Spartan 4F (down to 6.0 ounces of Spartan 4F) provided good to excellent control of yellow nutsedge. Control was poor at one location with pretransplanting (PRE-T) applications of Spartan 4F at labeled and below-labeled rates, which was likely due to low soil moisture at and immediately following transplanting.

Yellow nutsedge control from Tillam and Spartan Charge is similar for the first two to three weeks after transplanting. However, late-season nutsedge and grass control are poor with Tillam. Tillam is short-lived in the soil, so applying it several weeks before transplanting, which is common in fumigated fields, greatly decreases control. Spartan Charge provides season-long control of nutsedge and better grass control than Tillam. However, there are significant rotational restrictions on the Spartan Charge label for cotton and sweet potatoes. If either of these two crops is planned for the year following tobacco, Tillam is the only herbicidal option for nutsedge control.

In fields with a history of high grass populations, try combinations with Command (soil incorporated or applied to the soil surface before transplanting), Prowl (soil incorporated), or a remedial application of Poast (overtop or directed).

Morningglories

Several species of morningglory occur in tobacco fields throughout North Carolina. Morningglory vines wrap around leaves and stalks, interfere with harvest, and end up as foreign matter in cured leaves. This is especially true when mechanical harvesters are used. Spartan Charge is the only herbicide labeled for tobacco that will control morningglories preemergence. Although control of morningglories is more consistent when Spartan Charge is incorporated before transplanting (PPI), injury to tobacco is less likely with PRE-T applications of Spartan Charge than with PPI applications. Aim will control morningglories postemergence but must be applied in a manner that prevents contact of spray solution with the tobacco plant and must be applied prior to layby or after first harvest. (See the discussion of Aim in "Herbicide Application Post-directed Prior to Layby or After First Harvest" section below.)

Annual Grasses

Large crabgrass, goosegrass, and broadleaf signalgrass are the most common grass species found in tobacco fields. Command, Prowl, and Poast offer excellent control of these grasses. Command and Prowl provide similar grass control but offer different strengths depending on location, rotation, and application method as described on their respective labels. If small grains are grown for harvest immediately after tobacco or if the plant-back requirements for susceptible plants cannot be met for Command, then Prowl is the better choice. If common ragweed is

expected, Command is preferable and can be tank-mixed with Spartan Charge or Tillam for improved grass control (compared to Spartan Charge or Tillam alone).

In past studies, pretransplant-incorporated treatments of Spartan Charge/Prowl resulted in significant tobacco stunting, and the Tillam 6E/Prowl combination has also resulted in excessive stunting. If Prowl is needed in combination with Spartan Charge, broadcast and incorporate the Prowl before bedding to comply with the current label. Then apply the Spartan Charge to the soil surface on knocked-down beds just before transplanting. Poast can be applied overtop to actively growing grass weeds up to 42 days before harvest. One advantage of Poast is that it can be used for remedial control of annual grasses in fields where populations are not known or when problems develop after transplanting.

Common Ragweed

The presence of common ragweed in tobacco fields is related to higher incidence of Granville wilt because populations of the disease-causing bacterium can survive on the roots of this weed. Ragweed control in rotational crops, in skip-rows, and field borders is necessary to reduce populations of this weed and the persistent soilborne bacteria that causes Granville wilt. Command offers good control, and Devrinol provides fair control. Research in North Carolina has demonstrated that tobacco should be maintained free of common ragweed for at least the first two to three weeks after transplanting. After this period, tobacco is extremely competitive against newly germinated common ragweed and leaf yield/quality are not significantly reduced. However, control measures should still be employed to reduce seed bank contribution and to prevent contamination of harvested/cured leaf.

Redroot Pigweed and Palmer Amaranth

These large, aggressive weeds can grow as tall as tobacco and interfere with harvest. Spartan Charge and Prowl provide the best control, and Tillam and Devrinol provide good preemergence control. Based on limited data, it appears that control of redroot pigweed is good to excellent at lower-than-labeled rates of Spartan Charge, but that Palmer amaranth control is poor with lower-than-labeled rates. Prowl and Devrinol can be applied at layby for additional residual control of pigweed. Neither herbicide has postemergence activity on pigweed, and both must be applied before seedling emergence for acceptable control. In situations where dry conditions may have prevented full activation and maximum control with Spartan Charge, additional residual pigweed control may be needed to prevent late-season applications. (See the discussion of layby herbicides later in this chapter.) Aim will control small redroot pigweed and Palmer amaranth postemergence, but it must be applied in a manner that prevents contact of spray solution with the tobacco plant and must be applied prior to layby or after first harvest. (See the discussion of Aim in "Herbicide Application Post-directed Prior to Layby or After First Harvest" section below.) Redroot and Palmer must be smaller than four inches at the time of application for best results with Aim.

Horsenettle

Horsenettle (or ball brier) is a deep-rooted perennial that is present in tobacco fields throughout North Carolina. This weed is a host for tobacco mosaic virus, but none of the herbicides labeled for tobacco control it. Control measures in a rotational crop such as corn are effective and can reduce the potential for tobacco mosaic virus when tobacco is planted in following years.

HERBICIDE SELECTION AND APPLICATION

Certain herbicides may be soil incorporated or applied to the soil surface before transplanting, within seven days after transplanting, or at layby (Table 6-3). There are advantages and disadvantages to each application time depending on the herbicide and weed population. Remember that proper identification of weeds is essential for proper herbicide selection (Table 6-1) and that county Extension agents can help with identification. Also, always read the label before purchasing an herbicide to see whether the product controls the problem weed, to determine the proper rate, and to be aware of rotational restrictions.

Spartan and Spartan Charge

Spartan 4F has been the formulation for sulfentrazone used for several years in flue-cured tobacco. Sulfentrazone is also sold under the brand name of Spartan Charge, which contains a premix of sulfentrazone and carfentrazone-ethyl, the active ingredient in Aim herbicide. Both Spartan and Spartan Charge are labeled for use in flue-cured tobacco. However, the formulated amount of the active ingredient sulfentrazone is different. Growers should refer to the label as well as the conversion table below (Table 6-2) for conversion of the rate of Spartan Charge to deliver the correct amount of active ingredient. The addition of carfentrazone-ethyl to Spartan Charge does not increase residual activity over Spartan 4F but may provide additional burndown activity of broadleaf weeds when making a typical PRE-T or PPI application. Spartan Charge is not labeled for a layby application directed at the base of tobacco plants. Producers using Spartan Charge are encouraged to employ additional sprayer cleanout to decrease carfentrazone residue in tanks, spray lines, and nozzles.

In this chapter, discussion of the use of Spartan is interchangeable with Spartan Charge. Growers are reminded, however, to refer to the label for the appropriate rates given a particular soil texture.

Table 6-2. Conversion table for rate of Spartan 4F and Spartan Charge

Spartan 4F (oz)	Pounds Active Sulfentrazone	Spartan Charge (oz)
4.0	0.125	5.08
4.5	0.141	5.71
5.0	0.156	6.35
5.5	0.172	6.98
6.0	0.188	7.62
6.5	0.203	8.25
7.0	0.219	8.89
7.5	0.234	9.52
8.0	0.250	10.16
9.0	0.281	11.43
10.0	0.313	12.70
11.0	0.344	13.97
12.0	0.375	15.24

Pretransplant-Incorporated Herbicides (PPI)

Pretransplant-incorporated herbicides offer several advantages. Growers can tank-mix them with other chemicals to save one or more trips across the field, and rainfall isn't as essential for activity with them as it is for surface-applied herbicides. In addition, when poor field conditions delay transplanting, pretransplant-incorporated herbicides help prevent weed growth that may start in the freshly prepared soil.

The most important disadvantage is crop injury. Prowl, Tillam, and Devrinol have the potential to limit root growth and slow early season growth (stunting). Stunting is most likely during cool, wet springs. Poor incorporation, applying high rates, and tank-mixing two or more of these herbicides increase the chance of root injury.

Command occasionally causes leaf whitening, which is not a concern because the plant color returns to normal and growth is not restricted. Spartan Charge does not affect root growth directly; however, foliar symptoms and stunting have been observed. Foliar symptoms include browning along the lateral veins, midveins, and the leaf area between the lateral veins. As with other herbicides, stunting is more severe with cool temperatures, low rainfall, or other environmental stresses. Also, using a proper application rate and uniformly incorporating Spartan Charge is critical. The activity of Spartan Charge is strongly related to soil texture and organic matter, with injury most likely on coarse-textured, low-organic-matter soils.

Studies have found few differences in stunting between labeled and below-labeled rates of Spartan (down to 6.0 ounces of Spartan 4F). This is important to note because using Spartan Charge at rates below what is labeled may not provide desirable control of all susceptible weeds. In fact, the application method rather than the rate had the greatest impact on stunting

in all treatments in these studies. Stunting ranged from 0 to 8 percent when Spartan 4F was applied PRE-T compared to 3 percent to 31 percent with PPI applications. Therefore, the most consistent way to reduce risk for stunting from Spartan is to apply it PRE-T. The primary risk associated with PRE-T applications of Spartan Charge is that early season weed control may be limited when soil moisture is low at (or immediately following) transplanting. Also, recovery from stunting is typically rapid, especially under favorable growing conditions, and no yield loss has been recorded in multiple tests when labeled rates of Spartan 4F were used.

Spartan Charge is often tank-mixed with Command to broaden the spectrum of weeds controlled by either herbicide alone. In addition, field, greenhouse, and laboratory research has shown that adding Command in a tank mix with Spartan 4F can reduce injury. In some cases, when Spartan 4F injury was severe, plots treated with a Spartan 4F and Command tank mix had half as much early season stunting as those treated with Spartan 4F alone.

If stunting from any herbicide occurs, it is important to remember that slow plant growth is due to a poor root system or herbicidal effect rather than a lack of nutrients. Applying more nitrogen will not increase the growth rate but will contribute to rank growth, slow ripening, more unripe grades, and lower prices at the warehouse.

Poor incorporation is an important factor in crop injury. Uneven incorporation leads to areas of concentrated herbicide in the soil. When tobacco is transplanted into an area of high concentration, root growth is restricted, resulting in root-bare areas often found on shanks of stunted plants when Prowl, Tillam, or Devrinol was applied. With Spartan Charge or Command, the roots absorb more of the chemical, which results in foliar symptoms.

Tractor speed, disk shape, and disk size are all important for uniform incorporation. Finishing or smoothing harrows with small, spherical disks and field cultivators incorporate chemicals more uniformly than cutting harrows with cone-shaped disks. Also, finishing harrows and field cultivators incorporate the chemical half as deep as the implements run, whereas larger cutting harrows incorporate approximately two-thirds as deep as the disks are run. Deep incorporation increases the probability that the herbicide will contact tobacco root systems and injure them.

Tractor speed should be at least 4 to 6 miles per hour (mph), and the field should be cross-disked to distribute the chemical more evenly. Disking once and bedding the rows will not incorporate the herbicide uniformly. You should never rely on the bedding operation alone to incorporate an herbicide. Doing so drastically increases the probability of crop injury while decreasing the effectiveness of the herbicide. Herbicides should always be incorporated with the proper equipment before bedding. Rebedding fields treated with a surface application of Spartan Charge can cause significant plant injury. This is because the rebedding operation concentrates the herbicide in the root zone of tobacco.

Research has found no consistent differences in Spartan 4F injury related to incorporation equipment in any of four experiments. Researchers considered the effects of no incorporation before bedding, incorporation with a disk, incorporation with a field cultivator, and PRE-T

application to the soil surface. The lowest levels of injury were consistently observed with PRE-T applications. The type of incorporation equipment is only one factor that can influence distribution of the herbicide in the soil. Crop injury also can result from soil-applied herbicide movement during bedding and transplanting. Also, recent research using radio-labeled Spartan 4F shows that uptake, translocation, and metabolism in tobacco is very rapid and that metabolism of Spartan 4F by tobacco is likely the source of crop tolerance. Therefore, crop injury can occur because of poor incorporation of Spartan Charge, decreased metabolism due to transplant stress, or both.

Injury can be reduced by applying pretransplant herbicides at the lowest labeled rate that field and weed conditions allow, incorporating the herbicide properly, and applying only one PRE-T-incorporated herbicide (with the exception of Command, which can be safely tank-mixed with other herbicides).

Devrinol and Command may leave residues that stunt small-grain growth, as indicated on the product label, especially when they are soil-incorporated. If the small-grain crop is used only as a cover crop, this stunting is not a problem. The potential for carryover can be reduced by making band applications to the soil surface rather than by using soil incorporation or broadcast surface application. Check the label for restrictions on rotational crops and the use of cover crops.

Herbicide Application to Soil Surface Before Transplanting (PRE-T)

Command and Spartan Charge are labeled for soil-surface application before transplanting in addition to the more traditional pretransplant-incorporated method. This method is common in other crops but new to tobacco.

When applying herbicides PRE-T, apply other chemicals, including insecticides, nematicides, and fumigants, in the usual way before bedding. Before transplanting, knock down the beds to transplanting height and apply the herbicides to the soil surface. For best results, knock down the beds as close as possible to the time of transplanting (keeping in mind the worker reentry restriction on the Spartan Charge and Command labels). Do not knock off additional soil during transplanting.

Herbicides applied to the soil surface depend on water to move into the soil where weed seeds germinate. Therefore, the PRE-T application method fits well in irrigated situations. If rainfall does not occur within three to five days, a light cultivation or irrigation may aid in activating the herbicide. Lack of rainfall early in the season can result in reduced weed control when herbicides are applied to the soil surface. Reduced weed control due to low soil moisture was observed with Spartan4F applied PRE-T in some fields.

Spartan Charge has excellent activity on nutsedge, morningglories, and pigweeds. It is the only herbicide labeled for tobacco that controls morningglories, and it controls nutsedge better than Tillam. Spartan Charge controls grass better than Tillam but not as well as Prowl or Command. If high populations of annual grasses are expected, combinations of Command/Spartan Charge or Prowl/Spartan Charge provide better control than Spartan Charge alone (Table 6-1).

Studies have shown that tank-mixing Spartan 4F with below-labeled rates of Command can enhance control of large crabgrass when compared to equivalent rates of Command alone. Spartan 4F tank-mixed with half the labeled rate of Command controlled large crabgrass as well as a full rate of Command applied alone. Therefore, not only can tank-mixing Spartan Charge/ Command reduce injury to tobacco from Spartan Charge; you can use a reduced rate of Command and still obtain excellent control of large crabgrass. Spartan 4F tank-mixed with Devrinol showed similar enhancement of grass control. However, Devrinol does not give as good season-long control of annual grasses as Command. This represents only one year of data, so results may vary from one year to the next. Also, if ragweed is a problem, then reducing the rate of Command would not give adequate control.

Because of potential carryover of Spartan Charge, there is an 18-month planting restriction for cotton and a 12-month restriction for sweet potatoes. Therefore, careful planning for these crops in rotation with tobacco will be necessary if Spartan Charge is applied.

Herbicide Application Overtop within Seven Days after Transplanting (OT)

Command and Devrinol are labeled for application overtop of tobacco within seven days after transplanting. This method provides weed control similar to PRE-T application and offers the flexibility of application after transplanting. Application at transplanting is usually preferable to waiting up to seven days because it saves a trip through the field and the herbicide is in place before weed seedlings emerge.

Herbicide Application at Layby

In fields with high row ridges, previously applied herbicides are moved along with treated soil from between the rows onto the row ridge. This justifies layby applications of herbicide to row middles in fields with a history of severe grass problems.

Layby applications help extend grass control when a short-lived herbicide such as Tillam is used. Also, a layby application of Devrinol or Prowl following the earlier soil-incorporated Tillam will extend grass and small-seeded broadleaf (such as Palmer amaranth) control, and crop injury will be less than when a tank mix of Tillam and Devrinol or Prowl is used.

Some growers use drop nozzles to apply the herbicides to the row middles at layby. Devrinol can contact tobacco buds without injury, but avoid applying Prowl to tobacco buds to prevent injury. As with overtop applications, applying Devrinol and Tillam at layby depends on rainfall to move the chemicals into the soil and to make them active on germinating weed seed. They must be applied after a layby cultivation, which is necessary to remove existing weeds.

Using an herbicide at layby usually increases weed control in wet seasons. But yield is seldom increased unless weed populations are heavy. Therefore, layby applications should be considered on a year-to-year basis and used only when the season and weed situation justify the treatment.

There has been renewed interest in layby herbicide applications because of the prevalence of Palmer amaranth in many areas of North Carolina. Where dry conditions may have prevented maximum activation and control from PRE-T or PPI applications, Palmer amaranth has the ability to germinate mid- and late-season in the rows as well as row middles. In these situations, a layby herbicide should be considered. Unfortunately, there are few herbicide options that will provide postemergence control of Palmer amaranth; therefore, it is critical to recognize where the need for additional residual control will be needed and make the applications prior to pigweed emergence.

Herbicide Application Postemergence Overtop

Poast can be applied to actively growing grasses in newly transplanted tobacco up to 42 days before harvest. Application rates vary from 1 to 1.5 pints per acre, depending upon the size of grass weeds. Grasses must be fully covered by spray to ensure control. Add two pints of crop oil concentrate or one pint of Dash HC spray adjuvant according to label directions. Apply Poast overtop or directed in a band.

Poast may be desirable in many of the same situations mentioned in the above discussion of herbicide applications at layby. The main difference between Poast and other grass herbicides labeled for use on tobacco is that it is applied to actively growing grass weeds after emergence (see label for maximum height of weeds controlled). This allows growers to delay grass herbicide application until grass populations are known, or to provide control of grasses after other measures have failed.

Herbicide Application Post-directed Prior to Layby or After First Harvest

Aim can be applied using a shielded sprayer or hooded sprayer to emerged, actively growing weeds in the row middles prior to layby. Aim can also be applied after first harvest when nozzles are directed underneath the crop canopy. Damage can result if spray solution contacts the tobacco plant. Do not apply when conditions favor drift. Refer to the Aim label for specific recommendations regarding application precautions in tobacco. Also refer to the "Sprayer Calibration" section below for information on banded applications. Additionally, when Aim is used for weed suppression additional sprayer cleanout is necessary to decrease chemical residue in tanks, spray lines, and nozzles.

HAND REMOVAL OF WEEDS

Hand removal of weed escapes (weeds not previously controlled by cultivation or chemical treatments) is a last line of defense for preventing further contribution of viable weed seed to the soil weed seed bank. Research has demonstrated that hand removal of Palmer amaranth can be accomplished without significant impact to economic return in tobacco, specifically when preceded by an herbicide program that contains sulfentrazone. In two years of evaluation, tobacco value and economic return were similar when sulfentrazone was applied prior to transplanting and followed by one hand-removal event prior to first harvest. Value and economic return were reduced when sulfentrazone was excluded from the herbicide program, even

when hand removal was utilized. These measurements were further reduced in the absence of sulfentrazone and hand-removal efforts. Collectively, these results indicate that producers should consider hand removal of Palmer amaranth and the application of an herbicide labeled for Palmer amaranth suppression. Results from this study can be found in Table 6-3. Producers are reminded that hand removal should occur prior to seed maturity to prevent seed distribution.

Table 6-3. Tobacco yield, value, and economic return as influenced by weed control programs[a]

Weed Control Program[b,c]		Yield		Value		Economic Return	
Herbicide	**Hand Removal**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
Clomazone	Yes	1,523 b	2,127 c	2,123 b	3,794 b	-1,076 b	589 b
Clomazone	No	454 c	1,325 d	589 c	2,307 c	-2,566 c	-848 c
Clomazone + Sulfentrazone	Yes	2,411 a	2,876 a	3,899 a	5,120 a	717 a	1,932 a
Clomazone + Sulfentrazone	No	2,402 a	2,786 b	3,766 a	5,071 a	594 a	1,899 a

[a] Treatment means followed by the same letter within the same column are not significantly different.
[b] Clomazone (Command 3ME) applied PPI at 2.0 pts/acre.
[c] Sulfentrazone (Spartan 4F) applied PRE-T at 5.0 fl.oz./acre.

WEED SEED CONTAMINATION IN CURED TOBACCO

There is growing concern over weed seed contamination in tobacco exported to foreign markets. Weed seed have been found in shipments of tobacco to China. Many of those weed species are listed on the Chinese government's quarantine list. At this point, the Chinese government has not exercised the right to reject shipments, but this could change in the future. Weed seed contamination is a likely result of mechanical harvesters pulling in entire plants during the harvesting process. Growers should be aware that even when whole plants are removed prior to curing, the seeds are often left behind.

Practical ways to reduce weed seed in cured tobacco:

- Use an appropriate weed control program. Weed control programs are comprehensive plans that involve the use of labeled herbicides for tobacco production, post-transplanting cultivation, and hand weeding to remove larger weeds that herbicides and/or cultivation do not control. A comprehensive list of labeled herbicides and recommended application rates can be found at the end of this chapter and in the *2020 North Carolina Agricultural Chemicals Manual*.
- Consider deep tillage (> 8 inches) during field preparation. This will bury viable weed seed at a depth where germination is not feasible. Research in other crops has demonstrated that when certain seed are buried at this depth and left in place for an extended period

of time (36 months), their viability is reduced to less than 10 percent. Producers should be aware that deep tillage by itself is not enough to ensure complete weed control in tobacco production and does not take the place of an effective herbicide program. Research at NC State University has indicated that the benefits of seed burial are typically not observed after layby, particularly where aggressive post-transplanting cultivation has occurred. While cultivation is a necessary component of crop management, the practice can re-expose weed seed previously buried through deep tillage.

- Keep field borders free of weeds. As mechanical harvesters turn around at the end of harvest rows, they can pull up any large weeds that are present.
- Be aware that the high temperature (165°F) reached during the stem-drying phase is not high enough to kill seed.
- If fields display excessive weed pressure during the season, use manual labor to remove them before they begin to develop seed. If seed development does take place, hand removal may spread the seed to tobacco leaves. In addition, once weeds are pulled, remove them from the field, as this will prevent the seed bank from being replenished. This practice is also recommended in fields with a relatively low number of weed escapes, as just a few weeds reaching maturity can produce enough seed to build a significant population the cfollowing season. This point is specifically true for Palmer amaranth, which can produce more than 500,000 seeds per plant. In this scenario, hand removal of weeds can occur without significant economic cost. Producers should realize that hand removal of weeds is a last line of defense and, much like herbicide use, is only a single component of a comprehensive weed control program.

MITIGATING RISK OF CROP PROTECTION AGENT DRIFT/ TANK CONTAMINATION

Residues from crop protection agents (CPAs), labeled for tobacco or not, have always been a concern to the U.S. tobacco industry. While those herbicides used in transgenic crop production are not labeled for direct use in tobacco production, there is risk that drift from application to adjacent crops (corn, cotton, and soybean) might occur under certain environmental conditions. If CPA drift is suspected, contact your local Cooperative Extension office and an agent can assist with diagnosis. In addition, it is in a producer's best interest to notify their contracting tobacco company or companies that drift is suspected, regardless of the herbicide. Being as transparent and proactive as possible with this issue will be your best option. What follows are ways to mitigate the risk of CPA drift or tank contamination.

- If planting herbicide-tolerant crops and tobacco on the same farming operation, do not use the same application equipment for all crops. Having dedicated tobacco equipment should be the first line of defense. If the same equipment must be used, refer to the respective herbicide labels for appropriate sprayer cleanout guidelines. The *2020 North*

Carolina Agricultural Chemicals Manual is another information source for sprayer cleanout. Remember that rinse water must be disposed of according to federal, state, and local regulations.

- When applying CPAs, always follow the material label. Some materials have very specific information regarding application rate, application timing, nozzle selection, operating pressure (PSI), boom height during application, maximum wind speed, ground speed, buffer areas, and air temperature/humidity restrictions.

Communication with neighboring farmers about what CPAs and crop technology are being used in surrounding areas is critical in reducing the chance of drift-related issues.

SPRAYER CALIBRATION

Proper sprayer calibration is essential to getting desired results from any pesticide and to minimize crop injury. Applying too much herbicide wastes money, could harm the environment, and may cause excessive root injury or pose a threat of carryover in the soil. Too little herbicide may give inadequate weed control.

Before calibration of a field sprayer, certain equipment repairs may be needed. Refer to the *2020 North Carolina Agricultural Chemicals Manual* for proper cleaning procedures, nozzle selection, and other steps to be taken.

Broadcast Applications

Step 1. After completing the necessary cleaning and repairs, fill the tank with clean water and calculate your speed under field conditions. It is always more accurate to calibrate a sprayer under field conditions than on a hard surface. Never rely on a tractor speedometer. Measure off 88 feet in the field, travel this distance, and record the time. Eighty-eight feet per minute equals 1 mph, so if you travel this distance in 15 seconds, for example, you are going 4 mph (20 seconds equals 3 mph).

Step 2. Using the desired pressure, catch the output from each nozzle with the tractor engine speed in revolutions per minute (rpm) set for the speed you traveled in the field; the tractor does not need to be in motion for you to measure the output. Catch the output from each nozzle in jars (or other suitable containers) for one minute, measure the water in fluid ounces or milliliters, and determine the average output of all nozzles. If a nozzle has an output that is 10 percent lower or higher than the average, replace it.

Step 3. Convert the average output per nozzle into gallons per minute (gpm) per nozzle using the following formula. For example, if the average output is 25 ounces per nozzle per minute:

$$\text{gpm} = \frac{25 \text{ oz/nozzle/minute}}{128 \text{ oz/gal}} = 0.195 \text{ gpm per nozzle}$$

$$\text{Then, gpa (gal/a)} = \frac{\text{gpm} \times 5{,}940}{\text{mph} \times \text{w}}$$

where mph *is the previously calculated speed and* w *is the average nozzle spacing in inches.*

An example. You have a 10-nozzle boom with a nozzle spacing of 18 inches. You travel 88 feet in the field in 20 seconds, or 3 mph (see Step 1).

With the tractor standing still and the motor running at the same rpm traveled in the field, you catch the output from each nozzle at a desired pressure for 1 minute. You find that the average output for all 10 nozzles is 25 ounces per nozzle, or, if you are measuring in milliliters, 739 milliliters per nozzle (3,785 ml = 1 gallon).

$$\textit{Calculate gpm: } \frac{25 \text{ oz}}{128 \text{ oz/gallon}} = 0.195 \text{ gpm}$$

$$\textit{or } \frac{739 \text{ ml}}{3{,}785 \text{ ml/gallon}} = 0.195 \text{ gpm}$$

Now that you have gpm and mph you can calculate gpa:

$$\text{gpa} = \frac{\text{gpm} \times 5{,}940}{\text{mph} \times \text{w}}$$

$$\text{gpa} = \frac{0.195 \times 5{,}940}{3 \times 18}$$

$$\text{gpa} = 21.5$$

Suppose you want to apply 1.5 pints of an herbicide per acre, and you want to mix 300 gallons. To determine how much herbicide to add to 300 gallons of water:

$$\frac{(\text{recommended rate})\,(\text{gal to mix})}{\text{gpa}} = \frac{(1.5 \text{ pt})\,(300 \text{ gal})}{21.5 \text{ gpa}} = 21 \text{ pints}$$

This 300 gallons will treat 14 acres (300 gal / 21.5 gpa = 14 acres). Therefore, you would add 21 pints of herbicide per 300 gallons of water.

Band Applications

Band applications of overtop herbicides provide an excellent opportunity to minimize costs without sacrificing weed control. Calibration for band applications is quite simple, but take care to calibrate correctly to avoid excessive application. If you attempt to band Spartan Charge over the bed before transplanting, be especially sure to calibrate properly. Serious crop injury will occur if rates that are intended for the field acre are concentrated into an 18- to 24-inch band.

To calibrate a sprayer for band application, use the previous gpa formula. However, instead of using the nozzle spacing for w in the formula, simply substitute the width of the band you are spraying. This will give you the number of gallons per treated acre, not per field acre. Once you obtain the number of gallons per treated acre, you must convert it to gallons per field acre using the following formula:

$$\frac{\text{gpa}}{\text{(per field acre)}} = \frac{\text{Band width (inches)}}{\text{Row spacing (inches)}} \times \text{gpa (per treated acre)}$$

An example. You wish to apply Devrinol 50 DF at a rate of four pounds per treated acre in a 16-inch band on 48-inch rows. You follow the previously described calibration procedure (time the distance to travel 88 feet, catch output from nozzles, etc.) and obtain the average gallons per minute (gpm) per nozzle and the tractor speed (mph). Fill in the values in the formula, but substitute the band width for the average nozzle spacing (w).

$$gpa = \frac{gpm \times 5{,}940}{mph \times w}$$

$$gpa = \frac{0.195 \times 5{,}940}{3 \times 16} = 24 \text{ (per treated acre)}$$

The sprayer is putting out 24 gallons per treated acre; or, put another way, the sprayer is putting out 24 gallons per acre in the treated band. But this rate will cover more than one acre of tobacco because you are spraying only one-third of the land. To obtain the number of gallons per field acre, use the previously mentioned formula:

$$\frac{\text{gpa}}{\text{(per field acre)}} = \frac{\text{Band width (inches)}}{\text{Row spacing (inches)}} \times \text{gpa (per treated acre)}$$

$$\frac{\text{gpa}}{\text{(per field acre)}} = \frac{16}{48} \times 24 = 8 \text{ gpa (per field acre)}$$

The sprayer is applying eight gallons per acre of land. But for every 24 gallons of water added to the tank, you add four pounds of Devrinol 50 DF. Suppose you add 150 gallons of water to your tank. To figure the acreage of tobacco this will cover:

$$\frac{\text{150 gallons}}{\text{8 gallons/acre}} = 18.75 \text{ acres}$$

To figure the amount of Devrinol 50 DF to add to the tank:

$$\frac{\text{150 gallons}}{\text{24 gallons/acre}} = 6.25 \times 4 \text{ pounds} = \text{25 pounds of Devrinol 50 DF per 150 gallons of water}$$

Or for every 24 gallons of water added to the tank, add 4 pounds of Devrinol 50 DF.

It is easy to see how band applications save money on herbicides. In this example, you can spray three acres of tobacco with the band application method for the same cost as spraying one acre with a broadcast application.

Other calibration methods are described in the *2020 North Carolina Agricultural Chemicals Manual*.

Calibrating a Sucker Control Boom with Three Nozzles per Row

The formula used to calibrate a broadcast application can be used to calibrate a sucker control boom with multiple nozzles per row. The only difference is that the output from the three nozzles for a given row should be combined and regarded as one nozzle. Then the output from the three nozzles should be converted into gpm, and the result should be entered into the formula.

An example. You have a four-row boom with three nozzles per row (two TG-3s on the outside and a TG-5 in the center). Your row spacing is 48 inches and you want to travel 3 mph, so you adjust your speed to travel 88 feet in 20 seconds. You catch the output from all three nozzles on a particular row. (Catch the output for each nozzle separately to make sure that similar-size nozzles are within 10 percent of each other.) Then combine the output for all three nozzles for 1 minute. Suppose it totals 4,550 milliliters, or 154 ounces.

$$gpm = \frac{4{,}550 \text{ ml/min}}{3{,}785 \text{ ml/gallon}} \text{ or } \frac{154 \text{ oz/min}}{128 \text{ oz/gal}} = 1.20 \text{ gpm}$$

Then enter that value into the formula:

$$gpa = \frac{1.20 \times 5{,}940}{3 \times 48} = 49.5$$

If you want to apply a 4 percent contact solution, add two gallons of contact per 48 gallons of water. This will apply a 4 percent contact at 49.5 gallons of total solution per acre.

Some Useful Information for Calibrating a Sprayer

88 ft/ minute	= 1 mph
1 gallon	= 128 ounces
	= 4 quarts
	= 8 pints
	= 16 cups
	= 3.785 liters
	= 3,785 milliliters
1 ounce	= 29.6 milliliters
1 milliliter	= 1 cubic centimeter

A Precautionary Statement on Pesticides

Pesticides must be used carefully to protect against human injury and harm to the environment. Diagnose your pest problem, and select the proper pesticide if one is needed. Follow label-use directions, and obey all federal, state, and local pesticide laws and regulations.

Table 6-4. Chemical weed control in tobacco. NOTE: A mode of action code (MOA) developed by the Weed Science Society of America has been added to the Herbicide and Formulation column of this table. Use MOA codes for herbicide resistance management

Crop	Weed	Herbicide, Mode of Action, and Formulation	Amount of Formulation Per Acre	Precautions and Remarks
TOBACCO, FLUE-CURED Field, before transplanting	Most annual grasses and some broadleaf weeds plus nutsedge suppression	pebulate, MOA 8 (Tillam) 6 EC	2.7 qt	Apply to soil surface before bedding and immediately incorporate according to label instructions. Transplant as soon as possible. Early season stunting may occur under unfavorable growing conditions. Does not control cocklebur, morningglory, ragweed, or perennial weeds. Cultivate tobacco at least twice. See label for tank mixes with other pesticides.
	Some annual grasses and some broadleaf weeds	napropamide, MOA 15 (Devrinol) 2 XT (Devrinol) 50 DF	2 to 4 qt 2 to 4 lb	Lower rates usually adequate for most soils. Apply to soil surface and incorporate according to label instructions. Some early season stunting may occur under unfavorable growing conditions. Does not control cocklebur, morningglory, or perennial weeds. Gives some suppression of ragweed. NOTE: Do not seed crops not specified on label for 12 months after application.
	Most annual grasses and some broadleaf weeds	pendimethalin, MOA 3 (Prowl) 3.3 EC (Prowl) H_2O (Helena-Pendimethalin)	2.4 to 3.0 pt 2.0 to 2.5 pt 2.4 to 3.0 pt	Can be applied up to 60 days before transplanting. Apply before bedding and incorporate into soil according to label instructions. Some early season stunting may occur under unfavorable growing conditions. Does not control cocklebur, morningglory, ragweed, or perennial weeds.
	Annual grasses and some broadleaf weeds	clomazone, MOA 13 (Command) 3 ME (Willowood Clomazone) 3 ME	2 to 2.67 pt 2 to 2.67 pt	Excellent annual grass control plus control of certain broadleaf weeds, such as prickly sida, jimsonweed, tropic croton, smartweed, and common ragweed. Partial control of cocklebur; does not control pigweed, sicklepod, or morningglory. Some whitening of lower leaves may occur but plants should recover. Do not plant small grains or alfalfa in the fall or following spring after Command application. Apply no more than once per season.

Table 6-4. *(continued)*

Crop	Weed	Herbicide, Mode of Action, and Formulation	Amount of Formulation Per Acre	Precautions and Remarks
TOBACCO, FLUE-CURED Field, before transplanting	Broadleaf weeds, nutsedges, and some grasses	sulfentrazone, MOA 14 (Spartan) 4F (Willowood Sulfentrazone) 4SC (Helm Sulfentrazone) 4F (Shutdown) 4.16 sulfentrazaone + carfentrazone MOA 14 + 14 (Spartan Charge)	4.5 to 12 fl. oz. 4.5 to 12 fl. oz. 4.5 to 12 fl. oz. 4.5 to 11.8 fl. oz. 5.7 to 15.2 fl. oz.	Excellent control of pigweed, morningglories, and nutsedges. Application rate is based on soil type and organic matter. See Spartan 4F and Spartan Charge label for rate determination and application methods. Early season stunting may occur especially when incorporated. Rainfall or irrigation needed within 7 to 10 days of application for maximum weed control, particularly when surface applied. Observe rotational crop guidelines and application rates on label.
TOBACCO, FLUE-CURED Field, after transplanting	Most annual grasses and some broadleaf weeds	napropamide, MOA 15 (Devrinol) 2 XT (Devrinol) 50 DF	2 to 4 qt 2 to 4 lb (broadcast, see label for band application)	Apply overtop immediately after transplanting tobacco. See remarks for Devrinol under "before transplanting." NOTE: Do not seed crops not specified on label for 12 months after application. Small grain seeded for cover crop in fall may be stunted. Do not use small grain for food or feed.
	Annual grass and some broadleaf weeds	clomazone, MOA 13 (Command) 3 ME (Willowood Clomazone) 3 ME	2 to 2.67 pt 2 to 2.67 pt	Excellent annual grass control plus control of certain broadleaf weeds, such as prickly sida, jimsonweed, tropic croton, smartweed, and common ragweed. Partial control of cocklebur; does not control pigweed, sicklepod, or morningglory. Make a single broadcast application in a minimum of 20 gal of water. Apply no more than once per season. Apply over the top of tobacco plants immediately, or up to 7 days after, transplanting but prior to emergence of weeds. Some whitening of lower leaves may occur, but plants should recover. Do not plant small grains or alfalfa in the fall or following spring after Command application.

Table 6-4. *(continued)*

Crop	Weed	Herbicide, Mode of Action, and Formulation	Amount of Formulation Per Acre	Precautions and Remarks
TOBACCO, FLUE-CURED Field, after transplanting	Postemergence control of annual grasses	sethoxydim, MOA 1 (Poast) 1.5 EC	1 to 1.5 pt	Apply to actively growing grass not under drought stress. Apply in 5 to 20 gal of spray at 40 to 60 psi. Add 2 pt of crop oil concentrate per acre. Do not apply within 42 days of harvest. Do not apply more than 4 pt per acre per season. Complete coverage of grass required for control.
	Postemergence control of some broadleaf weeds	carfentrazone, MOA 14 (Aim) 2 EC	0.8 to 1.5 oz	Apply using SHIELDED SPRAYER or HOODED SPRAYER to emerged, actively growing weeds PRIOR TO LAYBY. Do not apply when conditions favor drift. MUST PREVENT CONTACT OF SPRAY SOLUTION WITH TOBACCO PLANT. See label for further instruction.
TOBACCO, FLUE-CURED Layby	Most annual grasses and some broadleaf weeds	napropamide, MOA 15 (Devrinol) 2 XT (Devrinol) 50 DF	2 to 4 qt 2 to 4 lb (band; see label for band application)	Apply in a band to row middles immediately after last cultivation. Lower rates usually adequate for most tobacco soils. Incorporate lightly or sprinkler irrigate, if no rainfall within 3 days after application. Do not apply more than a total of 4 lb of Devrinol per acre in a season. See remarks for Devrinol under "Before Transplanting" and "After Transplanting."
		pendimethalin, MOA 3 (Prowl) 3.3 EC (Prowl) H_2O (Helena-Pendimethalin)	1.8 to 2.4 pt 1.5 to 2.0 pt 2.4 to 3.0 pt	Apply to row middles immediately after last cultivation. Avoid contact with tobacco leaves. Use higher rate on medium- or fine-textured soils where grass infestation is heavy or if no herbicide was used previously. Rainfall or irrigation is needed within 7 days. Does not control emerged weeds.
TOBACCO, FLUE-CURED After first harvest	Postemergence control of some broadleaf weeds	carfentrazone, MOA 14 (Aim) 2 EC	0.8 to 1.5 oz	Apply AFTER FIRST HARVEST for control of actively growing, emerged weeds. Position nozzles 3 to 4 inches above the soil and directed underneath the crop canopy. Do not apply when conditions favor drift. MUST PREVENT CONTACT OF SPRAY SOLUTION WITH TOBACCO PLANT. See label for further instruction.

7. TOPPING, MANAGING SUCKERS, AND USING ETHEPHON

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Topping tobacco in the button stage (soon after the flower begins to appear) rather than later increases yield and body if suckers are controlled. When tobacco plants are not topped for three weeks after reaching the button stage, yields are reduced by 20 to 25 pounds per acre per day, or about 1 percent per acre per day when normal yields range from 2,000 to 2,500 pounds per acre. Higher yields reduce per-pound production costs for acreage-related inputs such as chemicals, fertilizers, equipment, and some labor expenses. In addition to improved yield and quality, early topping has other advantages:

- It usually allows topping to be completed before harvest begins, helping spread the workload away from the peak harvest period.
- It reduces the possibility of plants blowing over in a windstorm.
- It stimulates earlier root development, which increases fertilizer efficiency, drought tolerance, and alkaloid production.
- It helps to reduce buildup of certain insects because eggs and larvae are removed with the floral parts.

These significant advantages of early topping far outweigh the disadvantage of earlier sucker growth, which can be controlled with proper use of contact chemicals. Also, sucker growth is often greater as a result of improved varieties and fertility programs, as well as better control of root diseases through the cultural practices of crop rotation, early stalk and root destruction, resistant varieties, and the use of soil-applied pesticides. As a result of these improved practices, plant roots normally have a greater ability to absorb water and nutrients throughout the growing season. The result is a higher yield as well as a greater potential for sucker growth, especially on plants topped in the button stage.

CULTURAL PRACTICES TO REDUCE SUCKER PRESSURE

No matter what sucker control method is used, sucker control is facilitated by (1) managing tobacco in such a way as to reduce sucker pressure and (2) maximizing the effectiveness of chemical applications. Using a reasonable nitrogen fertilizer rate and striving for a uniform crop are two of the most important things that tobacco producers can do to facilitate sucker control and management.

Using a Reasonable Nitrogen Rate

Excess nitrogen stimulates sucker growth and delays maturity, which increases the probability of troublesome sucker regrowth in prolonged harvest seasons. A base nitrogen rate of 50 to 80 pounds per acre is suggested, plus adjustment for leaching if needed. The lower portion of the rate range is suggested for finely textured, fertile soils, especially if legume crops were grown in the field the previous year. The higher portion of the rate range is suggested for coarsely textured soils with topsoils deeper than 15 inches to clay. The data in Table 7-1 illustrate the importance of nitrogen rate for sucker control. When the recommended nitrogen rate was exceeded, suckers were more difficult to control. See chapter 5 in this book, "Managing Nutrients," for more information on determining nitrogen rates.

Table 7-1. Sucker control with various rates of nitrogen at Kinston and Reidsville, 1993[a]

Nitrogen Rate	Sucker Control (%)[a]
Recommended – 16 lb/acre	87
Recommended	80
Recommended + 16 lb/acre	66
Recommended + 54 lb/acre	55

[a] Average of two locations. All treatments received two fatty alcohol applications followed by 1.5 gal/acre of maleic hydrazide.

Striving for a Uniform Crop

Good plant uniformity in the field improves the chance for consistently good chemical sucker control. Therefore, it is essential to produce and use healthy, uniform transplants. Also, it is important to maintain soil pH in the range of 5.8 to 6.0, use fertilizer application methods that minimize salts injury, and use only labeled rates and proper incorporation methods for soil-incorporated pesticides, especially herbicides. Always follow label instructions for pesticides or fertilizers added to the transplant water. These practices reduce early season root injury and improve crop uniformity, which allows the crop to mature on a normal schedule. This reduces the time that good sucker control is needed, particularly if the nitrogen rate is not excessive.

CHEMICAL SUCKER CONTROL

Two primary types of chemicals are available for sucker control: (1) contacts (fatty alcohols), which kill small suckers by touching (burning) them; and (2) systemics, which restrict sucker growth without killing. Contact alcohol chemicals desiccate (burn) tender sucker tissue, whereas

systemic chemicals retard sucker growth by inhibiting cell division. Maleic hydrazide (MH) is the only true systemic suckericide because it is absorbed by leaves and translocated through the plant to small sucker buds. Flumetralin (Prime+, Flupro, and Drexalin Plus) is a contact-local systemic suckericide because it must touch the suckers to be effective, although it retards sucker growth by inhibiting cell division. Plucker Plus contains both flumetralin and a fatty alcohol. Each of these is discussed in more detail below.

In 2011, one purchaser of U.S. flue-cured tobacco only accepted tobacco without any MH residues. Growers who produce "pesticide residue clean" tobacco do this without using MH and have received a premium for their cured leaf. Therefore, there are essentially two approaches to chemical sucker control that producers must take: conventional programs that include MH or alternative approaches that control suckers without MH. A discussion of each approach and options for producers follow.

SUCKER CONTROL WITHOUT MH

Successful sucker control that does not use MH relies on reaching the maximum potential from the remaining tools at our disposal. The following is a discussion of using contacts and flumetralin to control suckers without MH.

Contact Fatty Alcohols

The purpose of contact fatty alcohol applications is to provide sucker control between early topping and the time at which the upper leaves are large enough to be sprayed with flumetralin without causing leaf distortion. Another major advantage of contact alcohols, especially where multiple applications are made, is to shorten the period for flumetralin to control suckers after topping. Successful sucker control without MH starts with proper application concentration and timing of contacts. Poor control with contacts cannot be corrected by flumetralin. Applications of contacts and flumetralin should be made only to the rows where the crop was transplanted, to facilitate as accurate a delivery of the product as possible.

Timing. You should make the first contact application as soon as 50 to 60 percent of the plants have a visible button. Timing of chemical application is important because neither contacts nor flumetralin will adequately control suckers longer than 1 inch. Contacts are more effective if applied three to five days apart when humidity is low and leaf axils are fully exposed—that is, generally between 10 a.m. and 6 p.m. on sunny days, except when the plants are wilted and temperature exceeds 90°F. Contacts should not be applied to plants that are wet with rain or heavy dew or that are severely stressed by drought.

Coverage of leaf axils and stalk rundown are essential for contact applications. Contacts should be applied with three nozzles per row (TG3-TG5-TG3 per row or equivalents), at a low pressure (20 to 25 pounds per square inch [psi]) and with a 50 gallons-per-acre delivery volume. Nozzle selection, pressure, and delivery volume are critical for proper droplet size, which leads to good stalk rundown and coverage.

Concentration. The degree of sucker control with contact alcohols is directly related to the ratio of chemical to water. Therefore, it is extremely important to mix a specific amount of contact chemical with an exact amount of water. The suggested ratio for the first application of C_8–C_{10} contact alcohol products (Off-Shoot T, Fair 85, Kleen-Tac, Sucker Plucker, Royaltac-M, etc.) is two gallons in 48 gallons of water; this makes a 4 percent solution. A 5 percent solution is suggested for subsequent applications of C_8–C_{10} contact alcohol products; this is 2.5 gallons in 47.5 gallons of water. The suggested ratio for the C_{10} products (Antak, Fair-Tac, Royaltac, Ten-Tac) is 1.5 gallons in 48.5 gallons of water; this makes a 3 percent solution. The mixtures should be strong enough to kill both of the tiny suckers in each leaf axil when the solution wets suckers less than one inch long. Using more than the suggested amount of water will weaken the mixture, and you will not obtain good control. Using less than the suggested amount of water will strengthen the mixture and may cause leaf burn on tender crops.

Table 7-2. Sucker growth with three different concentrations of C_8–C_{10} contact alcohol sprays

Contact + Water (gallons)	Percentage Solution	Suckers per Acre	
		(number)	(lb)
1 + 49	2	29,900	6,256
1.5 + 48.5	3	15,600	4,794
2 + 48	4[a]	7,800	1,950

[a]Normal suggested rate of 2 gallons of contact chemical in 48 gallons of water.

Weak contact solutions, those less than 4 percent for the C_8–C_{10} products or less than 3 percent for the C_{10} products, often control only one of the two sucker buds in each leaf axil. A good general rule is to apply a contact solution that chemically tops 5 to 10 percent of the small, late plants in a field. If no chemical topping occurs during the first application, the solution is too weak to provide maximum sucker control, or the application took place too late. Some growers worry about leaf drop with contact alcohol solutions. This is not likely to be a problem unless the crop has been overfertilized with nitrogen and the season is unusually wet for several days after application. Generally, the benefits of increased sucker control from full-strength contact applications far outweigh any negative effects of leaf drop.

Flumetralin (Prime+, Flupro, and Drexalin Plus)

Mechanical application of flumetralin (overtop sprays). Flumetralin should be applied like a contact solution: only to the same rows to which the crop was transplanted. The objective is to apply flumetralin so that it touches the small suckers just like contact solutions because, unlike MH, flumetralin does not move to sucker buds through the leaves. Flumetralin must first wet the suckers like a fatty alcohol contact before it can stop cell division like a systemic. Therefore, flumetralin is referred to as a contact-local systemic. It has no true contact activity, and the controlled suckers do not turn brown or black but rather look yellow and deformed for several weeks after treatment.

Because flumetralin needs to run down the stalk and wet the suckers, it should be applied with contact nozzles (TG3-TG5-TG3 per row or equivalents), with a delivery volume of 50 gallons per acre and at a low pressure (20 to 25 psi). Flumetralin does not completely control suckers longer than one inch, so you should remove larger suckers before application. Full-season sucker control can be expected on small suckers wetted by the flumetralin solution, but missed suckers will continue to grow and should be removed by hand. Missed leaf axils with flumetralin are typically in the top of the plant and may result from leaning stalks, leaves covering the leaf axil, or both, preventing proper "rundown" of flumetralin into all the leaf axils.

Even though the flumetralin label allows for application of up to one gallon per acre, the general recommendation has been for application rates of two quarts per acre. Increasing flumetralin rates from two quarts per acre to three quarts or one gallon in a single mechanical application has not consistently improved sucker control, primarily because control is so dependent on coverage of all leaf axils, which is not improved by increasing flumetralin rates. However, application of two quarts of flumetralin followed by one quart of flumetralin seven days later improves sucker control compared to three quarts of flumetralin applied in a single application. Plucker Plus from Drexel Chemical Co. contains both flumetralin and a fatty alcohol, so read the label carefully for additional instructions and precautions, and appropriate rate recommendations.

This would indicate that increasing rates of flumetralin above two quarts per acre is only advantageous if the flumetralin is applied in a split application. It is likely that split applications reduce the number of missed leaf axils—the main cause of poor sucker control when MH is not used.

Soil residues of flumetralin applied to tobacco may contribute to stunted early season growth of later crops, especially small grains and some vegetable crops, such as sweet potatoes and corn, but also nonrotated tobacco, particularly if excessive rates are used for sucker control on light, sandy soils. The carryover potential may be greater when a dinitroaniline is used for both weed and sucker control on sandy soils. (See product labels for comments on carryover residues and possible rotation crop injury.)

Dropline applications of flumetralin. Dropline applications are generally the most effective way to apply flumetralin because they allow for the most consistent ability to apply the flumetralin solution to each leaf axil. However, dropline applications require more labor, which is not always available on the farm depending on the scope of the farming operation or the degree of mechanization of other farming operations. Even though the best sucker control from flumetralin is achieved with dropline applications, growers must decide on a case-by-case basis whether such application methods are feasible and practical, depending on their individual situations.

A dropline application is made manually, with a single line per row, coming off of a powered sprayer (typically a high-clearance sprayer). Multiple lines can be used at one time, and each line

has a valve (trigger) and a single TG nozzle. Flumetralin is then applied on a plant-by-plant basis by manually holding the nozzle over the center of the plant and opening the valve or "trigger" long enough to apply a desired amount of solution to each plant, which is enough for the solution to reach the soil line at the base of the plant.

Dropline applications should be initiated when approximately half of the plants are in the elongated bud to early flowering stage. Plants should be topped and then flumetralin applied within 24 hours. In many cases, both topping and applying flumetralin with a dropline can be accomplished at the same time. Where uniformity is a problem and some plants are later to mature, a second trip through the field to top and dropline flumetralin only on those plants may be needed. If a second trip is needed, it can usually be accomplished at a faster speed than the original dropline application. Only apply flumetralin with a dropline once per plant per season.

Another advantage of dropline applications is that they can reduce the need for contact applications because dropline applications of flumetralin can be made at topping. In many cases, contact applications, when used in conjunction with a dropline application of flumetralin, are used only to allow the crop to "even out" so that all plants are at the correct stage for flumetralin application and only one trip across the field with droplines is needed. Contacts may also be used in this scenario to delay flumetralin applications for better management of labor resources by controlling sucker growth until labor is available.

In a dropline application, flumetralin should be mixed the same as with mechanical applications: two or three quarts of flumetralin in 49.5 or 49.25 gallons of water, respectively. The flumetralin solutions should be applied alone to deliver one-half to two-thirds of a fluid ounce of solution per plant. The intent is for the solution to reach the soil line with no excess, to reduce residues in the soil. Workers who perform dropline applications of flumetralin must wear personal protective equipment. Read the label for each source of flumetralin carefully (Prime +, Flupro, Drexalin Plus) to determine the requirements for dropline applications. Remember, Plucker Plus contains both flumetralin and a fatty alcohol so rate recommendations will differ from other flumetralin products.

SUCKER CONTROL WITH PROGRAMS THAT USE MH TO MINIMIZE MH RESIDUES

MH has saved many hours of labor since its introduction in the early 1950s. It is widely used for sucker control because it is relatively inexpensive, easy to apply, and usually effective. But high residues can reduce demand by both domestic and export customers. No suitable alternative to MH has been developed, and many sucker control programs without this product have not given consistently good results.

Periodic droughts and the adoption of improved varieties and cultural practices that emphasize yield extend the harvest season, which extends the period needed for good sucker control. Unfortunately, longer harvest seasons and greater use of mechanical harvesters have sometimes

led to excessive use of MH initially or in additional late-season applications. Consequently, MH residues on and in cured tobacco are often higher than acceptable to buyers.

Several members of the European Union, major importers of United States leaf tobacco, have adopted an MH tolerance level of 80 parts per million (ppm) for tobacco products. This tolerance may be established by other European countries in the near future. The major competitor for American-style flue-cured tobacco, Brazil, does not use MH and could capture a more significant share of the export market if MH residues on U.S. tobacco do not drop to and remain near the 80-ppm level.

Although an official MH tolerance has not been established in the United States, domestic cigarette manufacturers and all members of the industry are very concerned about poor public perception of any pesticide residues that could reduce tobacco use both here and abroad. Although domestic cigarette consumption is not increasing, the United States is a leading leaf exporter. Our continued success will depend partially on the domestic manufacturers' ability to provide cigarettes that meet current or potential pesticide tolerances in other countries.

MH is very water soluble, and residues vary substantially among years and regions. Residues are generally lower when both rainfall and yields are relatively high. Also, don't forget that the Farm Services Agency certification you sign annually states that all pesticides you used for flue-cured tobacco production were applied according to label directions. In addition to possible loss of domestic and export markets, continued overuse of MH could result in greater use restrictions.

It is important for the entire tobacco industry, including producers and farm supply dealers, to understand the significance of the pesticide residue issue to our industry, particularly to our export market. Also, it would be wise to assume that all pesticides that leave residues on tobacco (not just MH) will very likely undergo even greater scrutiny and regulation soon.

Early sucker control can be maximized with fatty alcohol contacts and flumetralin. This is essential if good sucker control is to be maintained with one application of MH at the labeled rate. Because contacts and flumetralin must touch the suckers to be effective, uniform row spacing, proper application speed, correct boom height, precise nozzle size and arrangement, and suitable pump pressure are all important for good sucker control. (See product labels for instructions.)

Proper Use of Contacts (Fatty Alcohols)

The degree of sucker kill with contact alcohols is directly related to the ratio of chemical to water. Therefore, it is extremely important to mix a specific amount of contact chemical with an exact amount of water. Most other chemicals used to control insects, weeds, and diseases do not share this requirement because growers need to add only enough water to uniformly distribute the chemicals.

The suggested ratio for the first application of C_8–C_{10} contact alcohol products (Off-Shoot T, Fair 85, Kleen-Tac, Sucker Plucker, Royaltac-M, etc.) is two gallons in 48 gallons of water; this makes

a 4 percent solution. A 5 percent solution is suggested for the second or third application; this is 2.5 gallons in 47.5 gallons of water. The suggested ratio for the C_{10} products (Antak, Fair-Tac, Royaltac, Ten-Tac) is 1.5 gallons in 48.5 gallons of water; this makes a 3 percent solution. The mixtures should be strong enough to kill both of the tiny suckers in each leaf axil when the solution wets suckers less than one inch long. Using more than the suggested amount of water will weaken the mixture, and you will not obtain good control. Using less than the suggested amount of water will strengthen the mixture and may cause leaf burn on tender crops.

Sucker control data (Table 7-2) show the great difference in sucker growth at final harvest when three different concentrations of a contact alcohol solution were applied. Suckers appeared to be under control for several weeks but then grew rapidly as the harvest season progressed, especially where the 2 and 3 percent solutions were applied.

Weak contact solutions, those less than 4 percent for the C_8–C_{10} products or less than 3 percent for the C_{10} products, often control only one of the two sucker buds in each leaf axil. Then the suggested rates of the systemic chemicals cannot control sucker growth on vigorously growing tobacco. Therefore, applying weak contact solutions may contribute to the use of excessive late- season applications of MH, which significantly increase MH residues on and in our cured tobacco. A good general rule is to apply a contact solution that chemically tops 5 to 10 percent of the small, late plants in a field. If no chemical topping occurs during the first application, the solution is too weak to provide maximum sucker control, or the application took place too late.

Some growers worry about leaf drop with contact alcohol solutions. This is not likely to be a problem unless the crop has been overfertilized with nitrogen and the season is unusually wet for several days after application. Generally, the benefits of increased sucker control from full-strength contact applications far outweigh any negative effects of leaf drop. Using a contact alcohol allows for earlier topping, which increases yields. Its purpose is to provide sucker control between early topping and the time when the upper leaves are large enough to be sprayed with a systemic chemical without causing distortion.

Timing of chemical application is also important because none of the chemicals, including MH, will adequately control suckers that are longer than one inch. You should make the first contact application as soon as 50 to 60 percent of the plants have a visible button. Contacts usually are more effective if applied three to five days apart when humidity is low and leaf axils are fully exposed—that is, generally between 10 a.m. and 6 p.m. on sunny days, except when the plants are wilted and temperature exceeds 90°F. Also, none of the products should be applied to plants that are wet with rain or heavy dew or that are severely stressed by drought.

Another major advantage of contact alcohols, especially where two or three applications are made, is that they shorten the period for the systemic chemical to control suckers after topping. Systemic chemicals containing only MH tend to "give out" six to seven weeks after application. When the harvest season lasts for 10 or more weeks, sucker regrowth often occurs. Flumetralin,

another systemic-acting chemical, controls suckers longer than MH does, but its control is further extended when preceded by one or two applications of alcohol contact.

Proper Use of Flumetralin (Prime+, Flupro, Plucker Plus, Drexalin Plus)

Flumetralin should be applied like a contact solution but not until the plants are in the elongated button to early flower stage. This is a few days before MH application is suggested. The objective is to apply flumetralin so that it touches the small suckers like contact solutions do because, unlike MH, flumetralin does not move to sucker buds through the leaves. Flumetralin must first wet the suckers like a fatty alcohol contact before it can stop cell division like a systemic. Therefore, flumetralin is referred to as a contact-local systemic. It has no true contact activity, and the controlled suckers do not turn brown or black but rather look yellow and deformed for several weeks after treatment.

Because flumetralin needs to run down the stalk and wet the suckers, it should be applied with contact nozzles (TG3-TG5-TG3 per row or equivalents) at a low pump pressure (20 to 25 psi). And because it is not absorbed and moved through the plant, it performs better than MH in dry weather. Applying flumetralin by hand (downstalk application) is likely to wet more suckers than mechanical spraying (overtop), but hand application requires more labor. Like other sucker control chemicals, flumetralin does not completely control suckers longer than one inch, so you should remove larger suckers before application.

Full-season sucker control can be expected on small suckers wetted by the flumetralin solution, but missed suckers will continue to grow and should be removed by hand. Missed suckers are likely to occur on leaning plants, whether treated with flumetralin or fatty alcohol contacts. Therefore, using MH in a tank mix with flumetralin or within a day or two after flumetralin application will control the missed suckers. This is why the most effective chemical sucker control programs include the use of both MH and flumetralin.

Soil residues of flumetralin applied to tobacco may contribute to stunted early season growth of later crops, especially small grains, corn, and sweet potatoes, but also nonrotated tobacco, particularly if excessive rates are used for sucker control on light, sandy soils. The carryover potential may be greater when a dinitroaniline is used for both weed and sucker control on sandy soils. (See product labels for comments on carryover residues and possible rotation crop injury.) To minimize possible injury to crops planted in the fall or following spring, follow label mixing and rate instructions and do not apply any more spray volume than required to run down to the bottom of the stalks. Rainfall within two hours after application could reduce effectiveness of flumetralin, but reapplication will also increase the potential for soil residue carryover. Therefore, do not reapply if flumetralin washoff occurs. Also, destroy stalks and roots after the last priming and bury them two weeks later with a moldboard plow set at a depth of five to six inches. Disk once or twice before planting a small grain cover crop.

Growers are advised not to exceed labeled rates of flumetralin whether used alone or in tank mixes with MH. Higher rates will not significantly improve sucker control but may make soil

residue levels high enough to stunt crops planted in the fall or spring. Also note that Plucker Plus is a mixture of flumetralin and fatty alcohol, read the label carefully for additional application instructions and precautions and rate recommendations.

Sucker control from flumetralin can be improved by making split applications, essentially dividing the desired total amount per acre into two applications made five to seven days apart, instead of all in one application. This is especially advantageous when reduced rates of MH are used or when sucker control without using MH is necessary. (See the discussion of MH-free tobacco earlier in this chapter.)

Apply the Labeled Rate of MH Properly

Unlike fatty alcohol contacts and flumetralin, MH is absorbed by leaves and moves within the plant to small sucker buds. Good absorption and systemic movement depend on having good crop growing conditions. Therefore, MH should never be applied on drought-stressed crops or on those wilted by too much rain, high temperatures, or both. It is best to apply MH one to three days after a good rain or irrigation. When irrigation is not available, many growers use flumetralin or one extra contact application to control suckers until enough rain comes for good MH absorption. This should be viewed as "buying time" until rainfall occurs. If soil moisture is adequate but afternoon temperatures will be high enough to cause partial wilting, MH should be applied only during the morning, starting when the leaves are just slightly wet with dew. Afternoon spraying generally is not suggested except on cool, cloudy days when soil moisture is good. It is extremely difficult for growers with large acreages and only one sprayer to take advantage of the best weather conditions for MH application; some should consider buying another sprayer or using larger nozzles to allow faster application.

The labeled rate of MH application on flue-cured tobacco is one quart per 1,000 plants. Most tobacco in North Carolina is planted at approximately 6,000 plants per acre. The correct rate for 6,000 plants is 1.5 gallons per acre. (This rate is suitable for most formulations available in North Carolina, which contain 1.5 pounds of active ingredient [ai] per gallon of product; some products contain 2.25 pounds of ai per gallon and should be applied at one gallon per acre for 6,000 plants per acre.) Only one application is permitted unless the first application is washed off by rain. Even then, research indicates that reapplication of the full MH rate is not needed unless a substantial rain occurs within four hours after the first application. Only a half-rate application (0.75 gallon of MH per acre) is needed if rain occurs between four and 10 hours after the first application. No reapplication is needed if rain occurs more than 10 to 12 hours after the first application. Following these important guidelines will ensure good sucker control with only minimal increases in MH residues.

MH is absorbed more effectively by younger, upper leaves than by older, lower leaves. Therefore, MH should be applied to the upper third of the plant using the three-nozzles-per-row arrangement. Some growers use drop nozzles with high pressure, as they do when spraying for aphids or flea beetles. This will not substantially improve sucker control but will increase MH residues because more of the spray is deposited on the undersides of leaves, where rainfall

is less apt to wash it off. Therefore, the use of drop nozzles for MH application is strongly discouraged. MH residues are often higher on lower leaves than on upper leaves because the lower leaves are harvested sooner after MH application.

MH is very water soluble but is not substantially degraded by sunlight or the high temperatures used during curing. The data in Table 7-3 illustrate the importance of rainfall in reducing MH residues. In these tests, MH application was followed 24 hours later by various amounts of irrigation to simulate rainfall. Lower and upper green leaves were sampled for MH residues immediately after irrigation. As little as 0.05 to 0.1 inch of irrigation significantly reduced MH residues on leaves from both stalk positions.

Table 7-3. MH residues on lower and upper green leaves following various amounts of irrigation, 1992–1993

Irrigation Applied (inches)	MH Residues[a] (ppm)	
	Lower	Upper
None	61	181
0.005	53	125
0.01	51	96
0.05	32	85
0.1	27	84
0.2	22	76
0.5	24	70

[a] All treatments received 1.5 gal/acre of MH. MH residues are averages of four experiments.

Timing of MH Application

MH is the most widely used chemical on tobacco grown in the United States. More recently, flumetralin—also a systemic suckercide, as MH is—has become popular among flue-cured growers, particularly in tank mixes with MH. Each product controls sucker growth by inhibiting cell division. Most MH labels stipulate that it must not be applied before the upper leaves are eight inches long to reduce possible stunting, a discoloration called "bronzing," or both. However, these abnormalities are sometimes observed when MH is applied on leaves longer than eight inches. Growth distortion of upper leaves treated with flumetralin also occurs, but less frequently than that associated with MH. Research suggests that the likelihood of discoloration and stunting from MH applications is greatly reduced when applications are delayed until upper leaves are sixteen inches long.

MH residues can also be reduced when the interval between application and harvest is maximized. The MH label states that you should wait at least seven days between MH application and harvest, with the anticipation that rainfall during this period will wash off some residues. If tobacco is ready for MH application and harvest, make every attempt to harvest first, then apply MH. It will most likely be at least seven days before the crop will be ready for another harvest. This will ensure MH-free first primings.

Once the rainfast period has passed following application of MH (10 to 12 hours), irrigation or rainfall can reduce MH residues without adversely affecting sucker control. After 10 to 12 hours, essentially all of the leaf absorption of MH that will occur has taken place. The residual MH left on the leaf surface contributes greatly to MH residues in cured leaf. Therefore, the washing off of MH through irrigation or rainfall has the effect of reducing overall residues. Table 7-3 illustrates the reduction of MH residues with various levels of irrigation applied 24 hours after application in research trials in 1992 and 1993.

Consider Using an Alternative Sucker Control Program

The most effective sucker control programs include proper use of the fatty alcohol contacts, flumetralin, and the labeled rate of MH. All of the newer programs provide better control than the traditional treatment of two contact applications followed by MH application (Table 7-4). These programs offer excellent, season-long sucker control without using more than the recommended rate of MH. The MH-flumetralin tank mix was used on more than 60 percent of the flue-cured acreage in 2002. The delayed use of flumetralin or another fatty alcohol application two to three weeks after MH involves an additional trip over the field but provides excellent late-season sucker control if applied before sucker buds exceed one inch in length. Apply the tank mix like a fatty alcohol contact, i.e., as a coarse spray (20 to 25 psi) using 50 gallons of spray volume per acre. Do not use the delayed flumetralin application if flumetralin was used for sucker control earlier in the season.

Topping and Sucker Control Programs That Include MH

Recommendations in this section for the use of MH are primarily related to achieving acceptable sucker control with minimal MH residues. Most recommendations in this section include 1.5 gallons of MH (2.25 lb ai). MH residues with 1.5 gallons of MH vary greatly across seasons and depend upon rainfall, irrigation, and harvest intervals. Generally, MH residues are lower in years with higher rainfall amounts. Irrigation and extending harvest intervals to wait on rainfall can lower residues in both dry and wet years. Because MH residues vary so greatly across growing seasons, it is not possible to recommend a rate that guarantees residue levels that are acceptable to all customers. However, reducing MH rates below the recommended rate of 1.5 gallons per acre can further reduce MH residues on a relative basis.

Acceptable sucker control can be achieved with rates below 1.5 gallons (2.25 lb ai) but requires using contacts wisely (see section on use of contacts) and potentially splitting applications of flumetralin (see section on using flumetralin). Research has shown that if maximum sucker control is achieved with contact applications and application of flumetralin is split (two quarts of flumetralin followed by a second application of flumetralin at one quart five to seven days later), rates of MH can be reduced to one gallon per acre (1.5 lb ai). In this scenario, MH is applied with the second application of flumetralin and after the first harvest. Plucker Plus contains both flumetralin and a fatty alcohol, so rate recommendations will differ compared to products only containing flumetralin.

Table 7-4. Sucker number and weight reductions with sucker control programs including Prime+, 1991–1994

Application[a]		Suckers Per Acre (Average/25 On-Farm Tests)	
Third	**Fourth**	**(number)**	**(lb)**
MH alone	None	13,644	1,697
(MH & Prime+) tank mix	None	1,575	380
MH alone	Prime+ (2 to 3 wk after MH)	557	165

[a] Third applications preceded by 4 percent and 5 percent fatty alcohol contact applications. Rates were 1.5 gal/acre for MH and 2 qts/acre for Prime+.

Several topping and chemical sucker control programs have been developed. Each is based on application of the correct rate of nitrogen (50 to 80 pounds per acre), depending upon soil type, with adjustments for leaching. Excessive nitrogen availability promotes excessive sucker growth as well as leaf drop and breakage. Proper sprayer calibration is important. See the sprayer calibration section in chapter 6, "Managing Weeds," for information on how to properly calibrate a spray boom with multiple nozzles per row.

Pay particular attention to label instructions regarding worker protection standards (see chapter 11, "Protecting People and the Environment When Using Pesticides"). This information provides specific requirements for personal protective clothing, restricted field reentry intervals, and other restrictions.

Overtop Application

Step 1. Apply an alcohol contact spray before topping when about 50 to 60 percent of the plants reach the button stage. The floral parts help to intercept sprays to increase sucker kill in the upper leaf axils. Use a 4 percent concentration for C_8–C_{10} products or a 3 percent concentration for C_{10} products. Using higher concentrations or application pressures other than those suggested on the product labels may cause substantial leaf burn, particularly for C_{10} products applied on tender tobacco when temperatures are unusually high.

Step 2. Top plants that are ready for topping 24 to 48 hours after the first contact alcohol application, making sure to follow label instructions regarding reentry into pesticide-treated fields.

Step 3. Make a second alcohol contact application three to five days after the first contact application. Use a 5 percent concentration for C_8–C_{10} alcohols (2.5 gallons in 47.5 gallons of water per acre) or a 3 percent concentration for C_{10} alcohols (1.5 gallons in 48.5 gallons of water per acre). Note: Drought-stressed plants or those with irregular growth and flowering may need a third alcohol contact application several days after the second, applied at the same concentration as the second application. An alternative for reasonably uniform plants with tip leaves at least 10 to 12 inches long is 0.5 gallon of flumetralin in 49.5 gallons of water per acre.

Step 4. Top any plants that were not topped during the first topping.

Step 5. Use one of these alternatives: (Note: Plucker Plus contains flumetralin and a fatty alcohol, so rate recommendations will differ compared to other flumetralin containing products.)

- **Alternative A.** Apply a tank mix of 1.5 gallons of MH (for products containing 1.5 pounds active MH per gallon) and two quarts of flumetralin per acre at the normal stage of leaf development for MH application. Apply as a coarse spray in 50 gallons of total solution per acre, as with contact alcohols (three nozzles per row: TG3-TG5-TG3 or equivalents; see "Nozzle Sizes, Arrangements, and Application Speeds" below). Use no more than three quarts of flumetralin per season to reduce the risk of soil residue carryover to following crops. Allow at least one week between MH application and harvest to minimize MH residues on and in cured leaves.
- **Alternative B.** Apply three gallons of FST-7 or Leven-38 in 47 gallons of water per acre about five to seven days after the second or third alcohol contact. Higher concentrations may cause leaf burn. Allow at least one week between MH application and harvest to minimize MH residues on and in cured tobacco. These products are a combination of a C_{10} contact alcohol and MH but contain 11 percent less MH than other MH products when used at labeled rates.
- **Alternative C.** Apply 1.5 gallons of MH per acre (for products containing 1.5 pounds active MH per gallon) about five to seven days after the second or third contact alcohol application. Allow at least one week between application and harvest to minimize MH residues on and in cured tobacco. MH alone usually does not provide adequate season-long sucker control compared to the tank mix described in Alternative A, and a fourth application of one of the products in step 6 below is often required to control late-season sucker regrowth.
- **Alternative D.** Instead of the second or third (if applicable) contact alcohol application, apply two quarts of flumetralin per acre mixed in 49.5 gallons of water, as mentioned in step 3, when the crop is at the elongated button to early flower stage. Apply by the dropline method or by tractor-mounted sprayer. With a tractor-mounted sprayer, apply as a coarse spray with low pressure just as you would for a contact application. About five to seven days after this application, apply the labeled rate of MH. Use flumetralin only once per season to reduce the risk of soil residue carryover to following crops. Allow at least one week between MH application and harvest to minimize MH residues on and in cured tobacco.

Step 6. Use if sucker regrowth is anticipated late in the season:

- **Alternative A.** Apply a 5 percent C_8-C_{10} contact solution (2.5 gallons in 47.5 gallons of water) using the standard application procedure for contact sprays. Do this about three weeks after MH application, when suckers are small and susceptible to contact burn. Remove suckers longer than one inch by hand before application.

- **Alternative B.** Apply two quarts of flumetralin per acre using the standard application procedure for fatty alcohol contacts (50 gallons of total solution per acre, three nozzles per row, low pressure). Apply about three weeks after MH application. Remove suckers longer than one inch by hand before application. Do not use this option if you applied flumetralin earlier in the season. Allow one week between MH application and harvest.

(Note: Plucker Plus contains flumetralin and a fatty alcohol, so rate recommendations will differ compared to other flumetralin containing products.)

NOZZLE SIZES, ARRANGEMENTS, AND APPLICATION SPEEDS

Except for MH applied alone, all currently labeled suckericides and mixes must be applied by methods that encourage stalk rundown in order to be most effective. When using the standard three-nozzle arrangement (TG3-TG5-TG3), application speed is limited to 2.5 to 3 mph to maintain the spray volume over the center of the row. Application of fatty alcohols and contact-local systemics, including tank mixes of these products with MH, is one of the slowest mechanical operations in tobacco production except for transplanting and perhaps mechanical harvesting of first primings. The ability to apply these products faster without lowering sucker control reduces manual and machine labor, improves timeliness of suckericide application, and allows more acreage to be sprayed when the weather is favorable. The increasing use of more precise application equipment, such as "high-boy" sprayers, may allow many growers to apply suckericides faster without reducing sucker control.

In ten field tests conducted in 1997 through 1999, a "high-boy" sprayer operated at 2.8 or 4.6 mph was used to apply each of several sucker control treatments. All applications at 2.8 mph were made with standard TG3-TG5-TG3 nozzles, and all applications at 4.6 mph were made with TG6- TG8-TG6 nozzles. Each combination of nozzle sizes and speeds delivered 50 gallons-per-acre spray volume per application on 48-inch rows. Sucker number and weight per acre did not increase with any of the sucker control treatments when applied at the faster speed.

In trials conducted in 2001 and 2002, sprayer modifications were made that allowed the same treatments to be applied at 3 and 6 mph. In addition, a number of field experiments were conducted to determine if several other "straight" or "cross" nozzle arrangements with four or five nozzles per row would improve sucker control at the 6 mph application speed. Several of the arrangements are illustrated below. An additional purpose of the 5-8 • 8-5 and both of the five-nozzle-per-row arrangements was to concentrate relatively more of the total spray volume over the row centers as compared to the three-nozzles-per-row arrangements.

3 Nozzles/Row	4 Nozzles/Row	5 Nozzles/Row
3—5—3	5—6•6—5	5 6 | | 3—8—3 3—6—3 | | 5 6
6—8—6	5—8•8—5	

The arrangements shown in Table 7-5 provided the best sucker control in these trials. The differences in sucker number and weight among the three arrangements were not statistically significant. The poorest performers on average were the five-nozzle-per-row arrangements, which concentrated a relatively higher percentage of the total spray volume over the row centers (data not shown). This implies that failure to keep these nozzle arrangements directly over the row may reduce sucker control relatively more than arrangements that supply more of the total spray to the sides of the row.

Table 7-5. Sucker numbers and weights per acre in nine experiments for a good sucker control program applied with three nozzle arrangements or sizes, 2001–2002

TG Nozzle Sizes (per row)	Gauge Pressure (psi)	Application Speed[a] (mph)	Suckers per Acre[b]	
			(number)	(lb)
Treatment: Contact (4%) + Contact (5%) + (MH & Prime+)[c]				
3—5—3	20	3	1,089	288
6—8—6	18	6	1,480	395
5—6•6—5	18	6	1,477	346

[a] Each speed delivers 50 gal/acre of spray volume for the nozzle sizes and gauge pressures shown.
[b] Averages of nine research and on-farm tests.
[c] Rates were 2 qt/acre Prime+ and 1.5 gal/acre MH.

These results indicate that growers who wish to apply stalk rundown suckericides at faster speeds can do so with confidence if they have uniform row widths, good sprayer equipment, and relatively level land, and if they treat only the number of rows that were transplanted. However, relatively simple three- or four-nozzle-per-row arrangements appear to provide sucker control as good as or better than the more elaborate five-nozzle arrangements tested to date.

No matter what arrangement you choose, be sure to calibrate your own application equipment for the row width, pressure, hose diameter, and strainer sizes to be used. Instructions for calibrating a sucker control boom are given in chapter 6, "Managing Weeds." After determining the output in gallons per minute (gpm), the speed needed to deliver the appropriate number of gallons of spray volume per acre (e.g., gpa = 50 gal/a) can be calculated by using the following formula:

$$\text{mph} = (\text{gpm} \times 5{,}940) / (\text{gpa} \times \text{row width (inches)})$$

USE OF ETHEPHON

Ethephon (Prep, Ethephon 6, Mature XL, Oskie, or Super Boll) is the only chemical approved for yellowing tobacco in the field. To use any other chemical for this purpose is illegal. Growers who do so—whether selling by contract or at auction—could cause considerable problems for themselves and for our industry.

Before spraying whole fields of tobacco with ethephon, test-spray some plants uniformly with hand kits available from agricultural chemical dealers, or prepare your own test spray by mixing one teaspoon of product in one quart of water. The purpose of test-spraying is to determine whether the leaves are mature enough to be induced to yellow. Test-spraying a few representative plants at several locations in each field and observing them two to three days later will help you decide if the tobacco will yellow as desired. This may be especially important in fields planted at different times, planted with different varieties, fertilized differently, topped at different heights, or otherwise managed differently. Ethephon should be used on the entire field only if plants respond well to test-spraying; if test leaves do not yellow within 72 hours, the crop is not mature enough to be sprayed or harvested.

Good spray coverage, especially of the leaf butts and uppermost leaves, is essential to achieve uniform yellowing. For overtop applications, apply the chemical in 50 gallons of spray per acre using a three-nozzle arrangement at a pressure of 40 to 60 psi. The finer the spray, the better the chance of it drifting inward toward the stalk and covering the leaf butts; consequently, 60 psi may give better coverage than 40 psi. Be sure to adjust the nozzles to ensure adequate coverage of all remaining leaves. Ethephon works more consistently when applied on warm, sunny days. Treat only the acreage that can be harvested in one day, and guard against leaf drop by not allowing treated tobacco to become overyellow before harvesting. Prep, Ethephon 6, Mature XL, and Super Boll contain six pounds of ethephon per gallon and are labeled to be used at $1^1/_3$ to $2^2/_3$ pints per acre. Oskie contains three pounds of ethephon per gallon and is labeled to be used at $2^2/_3$ to $5^1/_3$ pints per acre. Use the lower rate for normal crops and the higher rate for rank crops, particularly when temperatures are lower than normal at application time.

Producers should understand that ethephon and ethylene (curing gas) are two similar yellowing agents, both of which are used in different ways. Ethephon is applied to leaves in the field one to two days prior to harvest, while ethylene is injected into the barn during the yellowing phase of curing. Regardless of product, the goal is the same—to promote yellowing and thus reduce the amount of time required to sufficiently yellow tobacco during the curing process.

Research has consistently demonstrated that it is ethephon application in the field, rather than the addition of ethylene gas during yellowing, that has the greatest postive impact to yellowing duration (Table 7-6). Producers should realize that desired outcomes from ethephon application are most successful when tobacco is mature and beginning to ripen. Experiment three in Table 7-6 documents no change in yellowing duration when treated leaves were classified as under-ripe. In addition, the longer treated leaves remain on the plant the better the outcome. Same day

application and harvest are strongly discouraged due to reduced product assimilation and plant response, as well as label restrictions. Furthermore, research designed to compare yellowing time of leaves treated with ethephon four hours prior to harvest against injection of curing gas demonstrated similar yellowing time (106 vs. 105 hours, respectively). The field reentry time restriction for ethephon is 48 hours after application. Also, allowing 48 hours between spraying of ethephon and harvesting results in larger and more consistent reductions in curing time compared to earlier harvesting.

PRECAUTIONARY STATEMENT ON PESTICIDES

Pesticides must be used carefully to protect against human injury and harm to the environment. Diagnose your pest problem, and select the proper pesticide if one is needed. Follow label use directions, and obey all federal, state, and local pesticide laws and regulations.

Table 7-6. Effects of ethephon and/or ethylene gas on yellowing time (in hours) during curing (table adapted from Peele, 1994)

	Experiment One			Experiment Two			Experiment Three		
Yellowing Treatment	**UR**	**R**	**OR**	**UR**	**R**	**OR**	**UR**	**R**	**OR**
Nothing	84	71	65	68	61	49	70	66	51
Ethephon alone	60	47	44	52	49	42	70	54	37
Ethylene gas alone	84	71	65	68	61	49	70	66	51
Ethephon and ethylene	60	47	44	52	49	42	70	54	37

UR = under-ripe; R = ripe; OR = over-ripe

Table 7-7. Yellowing agents for flue-cured tobacco

Purpose	**Chemical**	**Amount of Formulation per Acre**	**Pounds Active Ingredient per Acre**	**Precautions and Remarks**
Increase the rate of yellowing	Ethephon (Prep) (Super Boll) (Mature XL) (Ethephon 6)	1.33 to 2.67 pt	1 to 2 lb	Use after second or third priming when remaining leaves are physiologically mature. Determine if tobacco is ready to spray by treating several representative plants at several locations with test kit. If test leaves begin to yellow in 24 to 72 hr, apply product to tobacco in 40 to 60 gal water per acre as a fine spray mist (40 to 60 psi). Effectiveness may be reduced by application on cool, cloudy days, poor spray coverage, or rain within 4 hr after application. Harvest leaves as soon as possible after REI on label or when they reach the desired degree of yellowness; prolonged delay in harvest may result in yield and quality loss or leaf drop. Therefore, do not spray more acreage than can be harvested before major rain is expected. DO NOT USE SURFACTANTS!
	(Oskie)	2.67 to 5.33 pt	1 to 2 lb	

Table 7-8. Chemical control of sucker growth

Chemical and Formulation	Purpose	Amount of Formulation per Acre	Precautions and Remarks
CONTACT TYPE			
C_8–C_{10} fatty alcohol (various brands) 6.01 lb/gal	Normal sucker control	2 or 2.5 gal (4% or 5%)	Apply in 48 gal of water per acre (4% solution) to plants in button stage with second application 3 to 5 days later at any time of the day, except when plants are wet or temperature exceeds 90°F or plants are wilted. Use two TG-3 nozzle tips plus a TG-5 in the center or equivalents per row with approximately 20 psi operated from 12 to 16 in. above the top of the button or stalk at 2.5 to 3 mph. Rate of second application may be increased to 2.5 gal in 47.5 gal of water (5% solution) unless crop is tender. Will not control suckers more than 1 in. long. Excess nitrogen increases the chance of leaf drop.
C_{10} fatty alcohol 5.72 lb/gal	Normal sucker control	1.5 gal (3%)	Apply in 48.5 gal water per acre (3% solution) for both applications. Follow application instructions above for C_8–C_{10} alcohol.
C_8–C_{10} fatty alcohol 6.01 lb/gal	Control of late-season sucker regrowth	2.5 gal (5%)	Apply 3 to 4 weeks after MH application if suckers begin to grow. Apply in 47.5 gal of water per acre. Follow same directions as above. Will not control suckers more than 1 in. long. Do not make more than three applications of a contact per crop per season.
SYSTEMIC TYPE			
Maleic hydrazide (MH) Liquids, various brands 1.5 lb/gal	Normal sucker control	1.5 gal (1 qt/1,000 plants)	Rate varies with plant population. 1.5 gal of the 1.5 lb per gal material assumes 6,000 plants per acre. For plant populations other than 6,000, adjust rate accordingly. Apply to plants 5 to 7 days after the last contact application. Apply in the morning, using 30 to 50 gal of water per acre, two to three cone nozzle tips per row, and 40 to 60 psi. Effectiveness will be reduced if applied to wet plants or those that are drought stressed or wilted from too much rainfall or high temperatures. Do not make more than one application per season. Should wash-off occur within 6 hr, a single repeat application may be made. DO NOT APPLY AT HIGHER THAN SUGGESTED RATES OR WITHIN 7 DAYS BEFORE HARVEST IN ORDER TO MINIMIZE MH RESIDUES.
Maleic hydrazide (MH) Liquids, various brands 2.25 lb/gal	Normal sucker control	1 gal (1 qt/1,500 plants)	
60% water-soluble products Fair 80 SP or Sucker Stuff 60 WS	Normal sucker control	3.75 lb	Rate for 6,000 plants per acre. Adjust rate accordingly for other plant populations.

Table 7-8. *(continued)*

Chemical and Formulation	Purpose	Amount of Formulation per Acre	Precautions and Remarks
SYSTEMIC TYPE (CONTINUED)			
Royal MH-30 SG	Normal sucker control	4 to 5 lb	
CONTACT-LOCAL SYSTEMIC TYPE			
Flumetralin (Prime+, Flupro, or Drexalin Plus) 1.2 lb/gal	Normal sucker control, power sprayer	2 qt	Mix in 49 gal of water per acre and apply as a contact at elongated button to early flower stage with three nozzles per row (TG-3, TG-5, TG-3). Remove suckers longer than 1 in. within 24 hr before application and remove missed suckers as observed later. Excess spray to the point of rundown on the soil increases the risk of carryover residues, which may stunt early growth of next crop, including tobacco if a dinitroaniline herbicide is also used. **Do not apply these products through any type of irrigation system, and apply only once per season.** Rainfall within 2 hr after application may reduce effectiveness. Follow WPS requirements and other precautions and restrictions listed on product labels.
Flumetralin (Prime+, Flupro, or Drexalin Plus) 1.2 lb/gal	Hand application	1.2 to 2.4 qt (2.5 oz/gal water)	Mix in desired amount of water at rates shown in parentheses and apply mixture as a coarse spray or drench to top of stalk. Apply about 0.5 oz of mixture per plant after topping and removing suckers longer than 1 in., but do not exceed 25 to 30 gal per acre. See remarks above for power sprayer application and follow precautions, restrictions, and WPS requirements shown on product labels.
Flumetralin (Prime+, Flupro, or Drexalin Plus) 1.2 lb/gal	Control of late-season sucker regrowth	2 qt	Apply only if control with MH is beginning to break down. Mix in 49 gal water per acre and apply as a contact at 20 to 25 psi 3 to 4 weeks after MH application; will not control suckers longer than 1 in. TO REDUCE THE RISK OF SOIL RESIDUE CARRYOVER, DO NOT USE FOR LATE-SEASON CONTROL IF USED EARLIER IN THE SEASON.
SYSTEMIC + CONTACT-LOCAL SYSTEMIC			
Maleic hydrazide (MH) + Flumetralin (Prime+, Flupro, or Drexalin Plus)	Normal sucker control	Full rate MH + 2 qt	See precautions and remarks for MH to determine "full rate" of MH. Mix in sufficient water to total 50 gal per acre, and apply 5 to 7 days after the last contact or when MH alone is normally applied. Apply as a contact, using three nozzles (TG-3, TG-5, TG-3) per row at approximately 20 psi. Follow precautions and restrictions on labels. DO NOT APPLY AT HIGHER THAN LABELED RATES OR WITHIN 7 DAYS BEFORE HARVEST IN ORDER TO REDUCE MH RESIDUES.

8. MANAGING DISEASES

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THE TOBACCO DISEASE SITUATION IN 2019

Diseases were a major concern for tobacco producers in 2019. The Plant Disease and Insect Clinic diagnosed over 140 independent samples. Of these, Pythium root rot, Tomato Spotted Wilt Virus, Granville wilt, Fusarium wilt, and leaf spots were common. The weather was a significant factor for the development of these diseases, and management is increasingly difficult with limited chemical management options.

Greenhouse disease is a continuing issue for producers. *Pythium* spp. were the primary cause of greenhouse disease, and management strategies are limited. *Pythium* spp. and other root rot causing fungi survive in soil and within the cracks of float trays, regardless of the material that the tray is made from. A sanitation and chemical management plan should be made prior to planting to limit losses associated with greenhouse diseases.

Although early in the growing season was dry, rainfall mid-season was favorable to the development of root rots. Warm, wet conditions in combination with damaged root systems were conducive for Granville wilt. Additionally, many of these stands with Granville wilt had secondary Fusarium wilt that mimicked symptoms of black shank. In parts of the piedmont production region where black shank was found, Fusarium wilt followed those infections as well. Although the cause for the abundance of Fusarium wilt is unknown, this year's environment was favorable to its spread.

Difficult-to-control leaf spots continue to be problematic for economic tobacco production. While there are efforts to label other fungicide chemistries that are effective on these leaf spots, the timeline for labeling may be longer than we would like to see. Continuing to rotate fungicide chemistries that we have available and maintaining good coverage of applications will hopefully limit the impact that these leaf spots have on production.

Moving forward, management strategies to maintain chemical efficacy against pathogens and improve control will be the primary focus of research objectives moving forward. Organic and conventional chemistries, variety resistance, and cultural methods continue to be investigated to help mitigate emerging and ongoing pathogen problems for N.C. tobacco. Look forward to

improved resources being available on the tobacco portal for disease management and updates on disease outbreaks.

DISEASE MANAGEMENT PRACTICES

An effective disease management program integrates a combination of cultural practices and chemical applications. No one practice alone can be relied upon to manage diseases. Disease management strategies must also be developed before the crop is planted in order to properly implement measures before diseases reach an economic threshold. Accurate identification of pests present, annual or seasonal disease severity, and environmental impact of disease and management practices are important in the selection of disease management method.

Crop Rotation

Most of the important diseases that occur every year are caused by organisms that persist in the soil and can reproduce only on tobacco and a few other plants. Without tobacco or one of the other host plants, populations of the disease-causing organisms are reduced. Therefore, crop rotation must be emphasized in planning any disease management program. Although growers may have valid reasons for having difficulty in rotating crops, the benefits that rotated crops can provide in disease control are great enough to merit careful planning and consideration. Many North Carolina crops are good rotation crops to help control tobacco diseases (Table 8-1).

Table 8-1. The value of various rotation crops in helping to manage selected diseases

Crop	Black Shank	Black Root Rot	Granville Wilt	Tobacco Mosaic Virus	Root-Knot
Corn	High	High	Mod.	High	Low
Cotton	High	Low	Mod.	High	None
Fescue	High	High	High	High	High
Lespedeza "Rowan"	High	Low	High	High	High
Milo	High	High	Mod.	High	Low
Peanuts	High	Low	Low	High	None[a]
Pepper	High	High	None	None	None
Potato, white	High	High	None	High	Low
Small grain	High	High	High	High	High
Soybean	High	Low	High	High	Low[b]
Sweetpotato	High	High	Mod.	High	Low[c]
Tomato	High	Mod.	None	None	None[b]

Note: These ratings are based on the assumption that weeds are well-managed in these crops. Ratings range from high to none. High = highly valuable as a rotation crop for this disease; none = no value as a rotation crop, may be worse than continuous tobacco.

[a] Rating may be high for certain root-knot species or races.

[b] Rating is high if a root-knot resistant variety of soybean or tomato is used.

[c] Rating is moderate if a root-knot resistant variety of sweetpotato is used.

Length of rotation. The longer the rotation, the greater the reduction of pathogens that persist in the soil. Thus, a four-year rotation (three alternate crops between tobacco crops) is more effective than a two- or three-year rotation. Similarly, a three-year rotation is superior to a two-year rotation. Nevertheless, a two-year rotation (one alternate crop between crops of tobacco) significantly reduces disease and is far better than continuous tobacco production. Where tobacco is grown continuously, farmers are "feeding" populations of pests, contributing to their buildup and the probability of severe disease problems in the future.

Stalk and Root Destruction

Roots and stalks from the previous year's crop must be destroyed, regardless of whether diseases have been observed (Table 8-2). To be effective, this must be accomplished as soon after harvest as possible. Completing these tasks reduces populations of several tobacco diseases, including black shank, Granville wilt, root-knot nematode, tobacco mosaic virus, brown spot, and tobacco vein banding mosaic virus, as well as certain insects, grasses, and weeds.

Furthermore, destroying old tissue exposes pests living in the tissues to adverse environmental elements. For example, root-knot nematodes are very sensitive to drying; if root tissue surrounding them decays, they are exposed to drying conditions. Tobacco mosaic virus (TMV) particles lose their ability to infect after they are freed from tobacco tissue. TMV carryover may be reduced from 5 percent to less than 0.1 percent by destroying tobacco roots and stalks.

Table 8-2. Stalk and root destruction

Step	Description
1	Cut stalks in small pieces with a bush hog or similar equipment the day harvest is complete.
2	Plow out stubble the day stalks are cut. Be sure to remove the root system entirely from the soil.
3	Re-disk or harrow the field about 2 weeks after steps 1 and 2 are completed. This provides additional root kill and exposes different areas of the root to the drying action of sun and wind.
4	Seed a cover crop where needed to prevent water and wind erosion. Postpone this seeding until roots are dead.

Resistant Varieties

Growers should not depend solely on resistant varieties for disease management. Even resistant varieties are sometimes severely damaged by disease, especially where rotation, stalk and root destruction, and other management tools are not used. Some varieties are highly resistant to only certain races or species of a particular pathogen. For example, root-knot-resistant varieties are only resistant against *Meloidogyne incognita*, races 1 and 3. Some of the varieties listed in Table 8-3 are highly resistant to race 0 of the black shank fungus but are quite susceptible to race 1. See the section on black shank for a more complete discussion of resistance to that disease, and see Table 8-4.

Table 8-3. Resistance of flue-cured tobacco varieties assessed across three years in the Official Variety Testing to black shank, Granville wilt, root knot nematode, and tobacco mosaic virus

	Black Shank			Granville Wilt				
Variety[a]	% Survival[b]	Disease Index[c]	Resistance[d]	% Survival[b]	Disease Index[c]	Resistance[d]	RKN[e]	TMV[f]
CC 13	57.43	22.74	M	41.95	24.78	M	R	S
CC 27	38.86	37.18	L	48.83	29.76	M	R	R
CC 33	71.32	14.87	H	40.67	32.99	M	R	S
CC 35	81.71	34.26	M	12.36	41.84	L	R	S
CC 37	39.08	24.10	M	66.87	19.83	M	R	R
CC 67	59.51	23.51	M	53.08	26.18	M	R	R
CC 143	55.58	6.94	H	46.07	28.91	M	R	R
CC 144	84.34	2.69	H	54.17	13.66	H	S	S
CC 145	90.61	2.47	H	35.00	14.95	H	S	S
CC 700	67.44	18.42	M	35.59	34.53	M	R	S
CC 1063	91.88	3.24	H	53.13	27.33	M	R	S
GF 318	60.32	19.17	M	41.32	33.23	M	R	R
GL 26H	53.22	16.10	M	41.79	26.09	M	R	R
GL 365	93.73	2.03	H	78.26	6.82	H	R	S
GL 395	67.06	16.53	H	44.86	32.90	M	R	S
GL 976	46.54	18.64	M	11.29	44.34	L	R	R
K 326	37.03	34.97	L	24.06	39.95	L	R	S
K 346	85.37	7.79	H	49.10	30.44	M	R	S
NC 71	43.52	32.49	M	27.27	39.42	L	R	S
NC 72	56.81	19.22	M	34.09	37.69	L	R	S
NC 95	43.43	25.32	M	44.35	24.82	M	R	S
NC 196	72.95	14.80	H	39.86	38.32	L	R	S
NC 297	36.78	43.76	L	55.07	19.71	M	R	R
NC 299	46.57	26.89	M	46.05	29.64	M	R	S
NC 606	77.33	9.23	H	67.38	17.13	H	R	S
NC 925	92.38	3.75	H	41.98	34.64	M	R	S
NC 938	86.90	7.29	H	50.59	29.53	M	R	S
NC 940	74.01	18.54	M	53.03	26.36	M	R	S
NC 970	68.37	11.70	H	4.40	56.94	L	R	S
NC 971	93.27	2.04	H	26.68	38.13	L	R	S

Table 8-3. *(continued)*

Variety[a]	Black Shank			Granville Wilt			RKN[e]	TMV[f]
	% Survival[b]	Disease Index[c]	Resistance[d]	% Survival[b]	Disease Index[c]	Resistance[d]		
NC 972	90.31	3.24	H	5.94	53.77	L	R	S
NC 1226	98.55	0.52	H	12.25	40.68	L	R	S
PVH 1015	64.18	17.02	M	41.94	30.42	M	R	S
PVH 1452	66.41	15.63	H	52.75	25.50	M	R	S
PVH 1600	64.34	21.22	M	21.22	47.47	L	R	S
PVH 1610	59.77	14.12	M	25.50	35.47	L	R	R
PVH 1920	78.25	6.49	H	52.96	28.62	M	R	S
PVH 2110	49.69	26.96	M	35.26	38.34	L	R	S
PVH 2254	49.58	21.68	M	43.32	34.96	L	R	R
PVH 2275	7.31	58.57	L	48.11	30.66	L	R	R
PVH 2310	29.80	38.17	L	37.05	30.04	L	R	R
PVH 2343	41.87	25.58	M	19.85	38.29	L	R	R
PVH 2408	9.81	56.61	L	70.44	11.94	H	R	R
PVH 2275	7.31	58.57	L	48.11	30.66	L	R	R

[a] Variety names followed by a * indicate a commercially available variety.
[b] % Survival ratings are the percent survival based on the observed percent of healthy plants across three years of data collection in fields heavily infested with disease. High ratings equate to a higher level of resistance.
[c] Disease Index ratings are the average disease index across three years of data and several growing regions heavily infested with disease. The lower the disease index rating, the higher the level of resistance in a given variety.
[d] Resistance level designated as L= Low, M = Moderate, and H = High.
[e] Varieties with resistance to root knot nematode = R, susceptible varieties = S.
[f] Varieties with resistance to Tobacco Mosaic Virus = R, susceptible varieties = S.

Fumigants, Fungicides, and Nematicides

Fumigants, fungicides, and nematicides give growers an additional tool to manage diseases. Fumigants primarily help manage Granville wilt and nematodes. More narrow-spectrum chemicals are also available to help control nematodes, black shank, and some other diseases. Protectant foliar fungicides are also available for target spot and Ridomil-insensitive blue mold management. All disease management chemicals must be applied before the disease is established.

It is essential to management with pesticides to identify the causal organism. Once correctly identified, it is important to select the appropriate chemical for the disease present. For soil applications, soil must be in good tilth as poor soil preparation lessens efficacy of soil-applied chemistries. Temperatures for soil or foliar applications must also be within a favorable range to avoid risk of injury to tobacco as well as provide the highest efficacy for a given product.

Additional Helpful Cultural Practices

The following practices give the plant every possible advantage to withstand attack by disease-causing agents. Carefully considering the impact of each practice on disease development and operating in ways that favor tobacco plant development work to the disadvantage of disease-causing agents and improve management of diseases in the field.

Formation of a high, wide bed (row). Developing a high, wide bed in the field helps provide proper conditions for tobacco roots to develop. This practice conserves soil moisture during dry periods and helps provide drainage for root systems in areas of fields that tend to become waterlogged. Most causal agents that affect the root systems of plants are favored by poor drainage and high moisture environments.

Spacing. Tobacco plants that are spaced too closely often suffer more disease than those planted farther apart in the row. In particular, spacing influences diseases such as brown spot, target spot, and blue mold. Wider spacing provides for more sunlight, better air flow through the canopy, and better drying conditions for the foliage at the bottom of the plant.

Balanced fertilization. Disease-causing agents are generally favored by imbalanced nutrients that may cause poor/irregular growth or prematurely senescent tissues. Some pests, such as root-knot nematodes, are favored by deficiencies in nutrients such as potassium. Other causal agents, including the black shank fungus, are favored by excessive nitrogen. Usually, a healthy crop is one that has received balanced fertilization—neither excessive nor deficient.

Order of cultivation when disease is present. If disease appears in only some fields or certain parts of a field, cultivate these areas last to reduce the chance of spreading the disease organisms to "clean" areas. After cultivation, wash equipment with a detergent solution at the same strength used to wash clothes.

MANAGING THE MAJOR DISEASES

Transplant Diseases

The following addresses only some disease problems that may occur in greenhouses in North Carolina. The condensed guide for seedlings is at the end of the chapter (Table 8-8).

Diseases in greenhouses. The most common diseases in greenhouses are caused by *Rhizoctonia*, *Sclerotinia* (collar rot), *Pythium*, and bacterial soft rot (*Erwinia* spp.). *Rhizoctonia* generally causes damping-off observed before clipping begins, and *Sclerotinia* causes damping-off after clipping. Damping-off caused by *Pythium* is preceded by extensive yellowing of the plants. TMV is rare under good sanitation practices, but it is devastating where it occurs.

Sanitation practices. Mowers can spread tobacco mosaic virus and bacteria. Wash and sanitize blades and the underside of the deck with 50 percent household bleach before each clipping of each greenhouse. Furthermore, be sure the mower thoroughly removes clipping debris (usually by vacuum). Clipping too much of the plant in one pass or allowing mower bags to get

too full causes more debris to fall back into the trays. Leaf debris in the trays or on the plants increases humidity in the plant leaves and is associated with collar rot and bacterial soft rot.

Before using trays that have been used before, thoroughly wash them and allow them to dry. Do not depend on dipping trays in any sanitation product, including bleach, to kill pathogens satisfactorily. Steaming trays at 176°F for 30 minutes is an excellent alternative to fumigation. Steaming trays at temperatures slightly below 176°F (no less than 158°F) for two hours can be used to get similar sanitation control as 176°F. Tray steaming will not destroy black root rot or TMV. Growers who know that greenhouse transplants were a source of TMV or black root rot should dispose of the trays that were used to produce infected transplants and purchase new ones.

Environmental conditions. Greenhouses should be fully ventilated when temperatures are not cold enough to damage the plants. Furthermore, to remove humidity from the greenhouse, place fans just above the plant canopy to circulate air around the structure. Polytubes or other power ventilators can also be used to remove humidity. Ventilation will help to reduce leaf moisture and subsequent disease. *Pythium* is most damaging at pH levels above 6.1 and at float water temperatures above 68°F. To keep the water temperature cool for as long as possible, do not fill the bays with water until it is time to float the trays. Closing greenhouses during July or August to allow temperatures to reach 140°F for eight hours per day for seven days helps kill pathogens. Heat sensitive items should be removed, and adequate moisture should be maintained in the house.

Other precautions: Never dump plants or used media within 100 yards of a greenhouse. Once diseased plants have been dumped, they may serve as a source for collar rot for up to five years. Walkways and entryways should be made of gravel, asphalt, concrete, or other material that can be easily washed. Boots worn outside the structure should not be worn inside unless they have been sanitized with a 10 percent bleach solution. Use special care in preventing field soil from contaminating water beds in float systems. Also, do not recycle pond water among beds because it can be a source of disease inoculum. Excessive and sloppy watering, poor drainage, plant injury, overcrowding, and excessive humidity most often lead to disease problems in greenhouses. Use only media produced for tobacco transplants. Do not introduce tobacco products into the greenhouse. Do not allow weeds, especially horsenettle, to grow in the greenhouse.

Tobacco should not be grown for any reason during a three-month period between October and February to ensure that blue mold does not overwinter. Should blue mold be a concern, spray Dithane Rainshield weekly after plants reach the size of a quarter to help prevent blue mold.

Field Diseases

The following sections present general information about some of the most common or recently discovered diseases. Diseases are listed in alphabetical order. A condensed disease management field guide begins at the end of this chapter (Table 8-9).

Black shank. Black shank is caused by a soil-inhabiting, fungal-like organism (*Phytophthora nicotianae*) that belongs to a group of the most destructive plant pathogens. This group of pathogens thrives in high-moisture climates. The black shank pathogen produces three types of spores, including a motile, swimming spore, that infect tobacco roots and sometimes infect stalk stems at leaf scars (where leaves fall off). Some leaf infection can be observed after rains that splash soil onto the leaves.

The symptoms of black shank are characterized by yellowing and wilting of leaves. Once infection occurs, death usually follows quickly. In highly resistant varieties, the symptoms on the stalks are usually confined to near-ground level. When stalks are split, the pith often appears blackened and separated into discrete discs. Although the presence of discs is not solely diagnostic of black shank and can occur because of other factors (i.e., lightning damage); likewise, not all plants suffering from this disease exhibit this symptom. Rotation, varietal resistance, and chemicals are usually integrated into a management program to reduce damages caused by black shank (Figure 8-1).

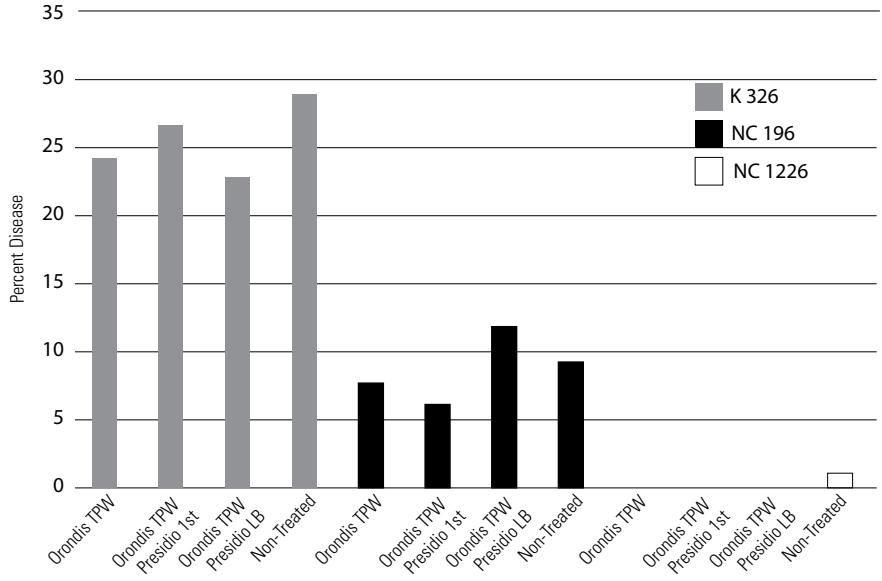

Figure 8-1. Flue-cured tobacco varieties (K 326, NC 196, NC 1226) with varying levels of resistance to black shank in combination with three different fungicide programs containing Orondis Gold (oxathiapiprolin + mefenoxam) and Presidio (fluopicolide) at the black shank nursery during the 2019 growing season. Fungicide programs reduced disease incidence of black shank, and in combination with variety may further limit disease development.

There are different sources of resistance used in available varieties. The FL 301 resistance has been the predominant form of resistance for many years. It is effective to varying degrees

against both race 0 and race 1 of black shank fungus. Many commercial flue-cured varieties have some level of FL 301 resistance. For example, K 346 has a high level, while K 326 has a low level. Another incorporated form of resistance imparts complete resistance (immunity) to race 0 of the pathogen but is susceptible to race 1. This complete resistance is controlled by a single gene (*Ph*). Any tobacco variety containing this gene will be completely resistant to race 0; however, varieties with the *Ph* gene may vary in their resistance to race 1 depending on the FL 301 resistance that is in their heritage. Currently, most varieties with the *Ph* gene have little FL 301 resistance, which means they will be more susceptible to race 1 than older varieties, such as K 346, that have high levels of FL 301 resistance. Most new varieties released over the past 5 to 10 years have the *Ph* gene, similar to the proportion of varieties that currently have the MI gene for races 1 and 3 of the southern root-knot nematode. Therefore, over time, the *Ph* gene has become a less effective tool. Whenever varieties with the *Ph* gene are planted crop after crop, race 1 becomes more prevalent, even if it was not initially the predominant race.

An additional resistance gene, *Wz*, confers resistance to race 1 and race 0. Although this new gene adds another tool, recent research has demonstrated that *P. nicotianae* populations can overcome resistance when challenged by repeated plantings of tobacco containing this gene. Rotation of host resistance traits and use of fungicides may help prevent fungicide-resistant pathogen populations from developing.

When applying fungicides for black shank control, timing is very important. Early applications (i.e., within the first seven to 10 days after transplant) are the most critical for effective control. Plants may be infected but have not shown symptoms yet, and fungicides will not provide control at that point. Fungicides applied to the soil surface should be incorporated by cultivation. Fungicides are only systemic upwards through the plant, and the primary target for black shank control is at the roots.

Fluopicolide (Presidio) became available to tobacco growers for control of black shank (and blue mold) in 2015, and oxathiapiprolin (Orondis) became available in 2016. Presidio should not be used in the transplant water due to the risk of phytotoxicity of young plants. Orondis is most effective when used in transplant water. These products should be incorporated into a black shank fungicide rotation to reduce the potential for fungicide resistance development. Additional factors, such as irrigation, damage from nematodes, and number and depth of cultivations may influence the severity of black shank in a field.

Blue mold. Blue mold is caused by an airborne fungus (*Peronospora tabacina*), and it caused widespread losses in North Carolina in 1979 and 1980. During those years, the disease occurred in fields as well as in plant beds. The fungus also spreads when infected seedlings are shipped. Its occurrence was sporadic until 1995, when it became widespread again. It has since become less common, and has only recently been found in one county of NC in 2016 and 2017.

Foliar infection by blue mold is characterized by the development of round, yellow spots with gray or bluish-gray mold on the undersides of the leaves. These spots rapidly multiply in

favorable environmental conditions (high humidity and cool temperatures) and coalesce to kill entire leaves. Old blue mold lesions are tan to white. When systemic, the fungus penetrates the plant, interfering with normal plant growth and resulting in stunting, distortion, and eventual death of the plant. Either type of infection can cause severe losses under favorable environmental conditions.

Because air currents disperse this fungus, crop rotation and stalk and root destruction do not affect this disease in North Carolina. The fungus does not overwinter in North Carolina, so predicting future infestations and their sensitivity to mefenoxam is not possible. It is likely that some blue mold lesions will be sensitive, and a Ridomil Gold application will be of some benefit. Acrobat MZ, foliar-applied protectant fungicides, or Actigard are needed for Ridomil-insensitive blue mold. Acrobat MZ is no longer manufactured and has been replaced with Acrobat 50WP. Acrobat 50WP has also been replaced with a liquid formulation of dimethomorph (Forum). The label requires application of Forum only in tank mixtures with Dithane DF Rainshield (mancozeb). In 2015 a second fungicide, fluopicolide (Presidio), became available to tobacco growers for the control of blue mold.

Brown spot. Brown spot is caused by an airborne fungus (*Alternaria* spp.). It may be considered an "opportunistic" disease-causing agent because it causes damage to senescent or damaged tissues. It does not usually become a problem in varieties tolerant to this disease if good cultural practices, such as proper planting density and canopy management, are followed. However, during periods of extended rainfall late in the harvest season, it can become destructive. It may also be destructive on prematurely senescent tissues or where plants become damaged from other environmental conditions.

Fusarium wilt. Fusarium wilt, although not destructive in all parts of the state, is significant in certain areas. It is caused by a fungus that lives in the soil (*Fusarium oxysporum* f. sp. *nicotianae*) and is well adapted for survival there. It can live well on decaying organic matter in the soil and forms spores (chlamydospores) that are very resistant to adverse conditions. Fusarium wilt is not as aggressive as some other diseases, such as Granville wilt or black shank, but it is also considered an "opportunistic" disease. If tobacco plants are stressed in certain ways, such as by root wounding or nematode infection, significant fusarium wilt may develop. Although crop rotation and stalk and root destruction are beneficial to some extent, these practices do not drastically reduce fusarium wilt development because of the fungus's ability to live on organic matter and form strong, resting spores.

Granville wilt. Granville wilt appears first as a wilting on one side of the plant. As the disease progresses, the entire plant wilts and then dies. When plants survive they are usually stunted, and their leaves may be twisted and distorted. The stalk usually becomes dark, especially at the ground level. At this stage, Granville wilt may be easily confused with other diseases, such as black shank. A diagnostic characteristic of Granville wilt is the streaks that extend up the stalk just beneath the outer bark.

Granville wilt is caused by a bacterium (*Ralstonia solanacearum*) that inhabits the soil. Infection occurs when these microscopic bacteria enter wounds or openings in the root system. Hence, cultivation and nematode damage can increase the incidence of this disease. Also, roots may become damaged as they grow through the soil. Therefore, Granville wilt bacteria usually have no difficulty locating a suitable entry point into the plant.

It is important to remember that Granville wilt bacteria inhabit the soil because anything that moves soil containing the bacteria will spread the disease from place to place. This can happen in many ways: by moving soil on machinery and other equipment, by water washing soil from one part of the field to another, by moving transplants with infested soil around the roots, or by any other means by which infested soil is moved.

Relatively high soil temperatures and adequate to high moisture levels in soil favor Granville wilt bacteria. Wet seasons greatly increase infection by Granville wilt bacteria. Infection may not be noticed immediately because wilting symptoms may not appear until plants are under moisture stress. Thus, it is not unusual to observe symptoms of Granville wilt several weeks after infection initially occurs.

Granville wilt bacteria also can infect tomatoes, white potatoes, peppers, eggplants, and peanuts. Ragweed, common to most of North Carolina, can also be infected and should be controlled. See Table 8-4 for management recommendations.

Table 8-4. Granville wilt management

Cultural

1. Rotate with fescue, small grains, or soybeans. Control weeds.
2. Use varieties with high levels of resistance (see section on variety selection).
3. Destroy stalks and roots immediately after harvest.
4. Avoid root wounding.
5. Manage nematodes.
6. Fumigate in the fall or spring with one of the following treatments.

Fumigants—Allow three weeks from application to transplanting

Chemical	Rate (gal/acre)	Method	Relative Control Rating*
Chloropicrin	5–6	Broadcast	Very Good
Chloropicrin	3	Row	Good
Pic +	4	Row	Good

*Actual control varies depending on other control practices and environmental conditions.

Hollow stalk (Soft rot). Hollow stalk or soft rot (caused by *Erwinia* spp.) usually appears first near topping and suckering time. It may begin at any stem wound and is often seen in the pith at the break made by topping. Soon after infection, a rapid browning of the pith develops, followed by general soft rot and collapse of the tissue. Top leaves often wilt, and the infection spreads downward; the leaves droop and hang down or fall off, leaving the stalk bare. Diseased areas may appear as black bands or stripes that may girdle the stalk. In another phase of the disease, a soft decay appears at the junction where leaf petioles are attached to the stalk.

Causal bacteria are usually present in soil and on plant surfaces. They may also be present on workers' hands as they top, sucker, or harvest the crop. These bacteria are often unimportant unless there is frequent rainfall and high humidity, which favors infection and subsequent disease development. The use of some contact sucker control agents may also lead to an increase in hollow stalk, especially if leaf axil tissue is damaged.

If affected leaves are harvested when wet and carried to the barn, they often develop barn rot during curing. Infection is most likely if ventilation is inadequate.

Pythium stem rot. This disease is caused by a group of *Pythium* species that include *Pythium aphanidermatum* as the most important and aggressive species, followed by *P. ultimun* var. *ultimun* and *P. myriotylum*. *Pythium* was believed to affect only tobacco seedlings in the early stages of growth after being transplanted in the field, causing damping-off, root and stem rot, and feeder root necrosis. In the last several years, *Pythium* was also detected affecting tobacco at different growth stages in the field (stages 4 to 8). Symptoms of *Pythium* stem rot are very similar to those caused by black shank, making loss estimates difficult. In most cases, *Pythium* stem rot affects some roots at the soil line level and most of the lower stem, causing a sunken black lesion that will continue to grow upward in the stem. Wilting of plants and chlorosis are also observed in plants affected by *Pythium*.

The predominant *Pythium* species (*P. aphanidermatum*) has not been detected on tobacco transplants produced in greenhouses in North Carolina; thus, the potential of carrying *Pythium* infected transplants with this pathogen from greenhouses is minimal. However, other *Pythium* species can be carried on infected transplants from the greenhouse and cause seedling blight. Spores of *P. aphanidermatum* can survive in the soil and plant debris in the field, and can infect a large number of host plants, including peppers, tomatoes, corn, cucumbers, and peanuts, among others.

High temperatures and soil moisture favor the development of *Pythium* stem rot. Because the incidence of this disease depends on environmental conditions, the development of control strategies is very difficult to generalize. Management of *Pythium* is similar to that for black shank, although resistance to this disease has not been identified.

Root-knot nematodes (and other nematode problems). Nematodes are microscopic roundworms that require living plant tissue to survive and complete their life cycle. Nematodes that attack tobacco live in the soil and are spread when infested soil is moved. Because nematodes are highly specialized organisms, knowledge of their biology and of how plants respond to them is necessary to develop a profitable management plan. The key to nematode control is to keep populations at nondestructive levels. Although a single nematode is not harmful, high populations have a devastating effect. Root-knot nematodes complete their life cycle, under favorable conditions, in only three weeks. Thus, in North Carolina they can produce as many as seven generations during one tobacco-growing season.

The most important nematode on tobacco in North Carolina is the root-knot nematode, *Meloidogyne incognita*. However, other *Meloidogyne* species are increasing in this state, especially *M. arenaria*, *M. javanica*, and *M. hapla*, which are severely damaging. The spread of *M. javanica* and *M. hapla* is a threat to root-knot control in the state because of the lack of resistance to them and the possibility that some non-fumigant nematicides may not effectively control them. Also, certain races of *M. incognita* that can attack root-knot resistant varieties appear to be increasing in the state. More recently, *M. enterolobii* has been introduced into North Carolina, and has been confirmed in five counties. This nematode species is particularly aggressive, and is difficult to control. If *M. enterolobii* is suspected in a field, contact the N.C. Cooperative Extension county agent, and submit a sample for DNA confirmation to the NCDA nematode assay lab.

To determine the infestation level of root-knot nematodes, examine the roots and have soil assays completed. A combination of these techniques provides excellent insight. First, observe the roots at random just after fall stalk and root destruction (immediately after harvest). You can estimate the infestation level by observing the area galled and using the following index:

- Low infestation—0 to 10 percent of root area covered with galls
- Moderate infestation—11 to 25 percent of root area covered with galls
- High infestation—26 to 50 percent of root area covered with galls
- Very high infestation—51 to 100 percent of root area covered with galls

The risk posed by moderate to high infestations is often equal to or greater than the risk posed by very high infestations. Even low to moderate infestations on a nematode-resistant variety warrant rotation to a non-host crop. The higher the gall index, the higher the infestation level. You can learn much about the root-knot population in each field by systematically assessing such indices. This information will prove valuable when making decisions about soil nematicide treatments or the use of a root-knot resistant variety.

To obtain nematode assays for all nematode species, take soil samples from the field and send them to the Agronomic Division, Nematode Assay Section, North Carolina Department of Agriculture and Consumer Services, 4300 Reedy Creek Road, Raleigh, NC 27607-6465. Contact your county N.C. Cooperative Extension agent for help. These samples must be taken in the fall (before December 1) to provide reliable information. No more than four acres should be represented by one sample, which should consist of at least 20 cores or subsamples from 6 to 8 inches deep. Samples must not be allowed to dry or heat above 80°F. The counts obtained from samples taken in the spring are usually much lower and are therefore not nearly as reliable.

As with other tobacco diseases, control of root-knot and other nematodes must be based on a combination of suitable practices; no one approach can provide adequate, long-term control. Recommendations for nematicides are presented in Table 8-5.

Table 8-5. Nematicides for root-knot nematode control on flue-cured tobacco

Material[a]	Rate/Acre	Method of Application	Waiting Period	Control Rating[b]
Chloropicrin 100 (chloropicrin)	3 gal	Fumigant—row[c]	21 days	Fair
Chlor-O-Pic 100 (chloropicrin)	3 gal	Fumigant—row	21 days	Fair
Pic + (chloropicrin 86%)	4 gal	Fumigant—row	21 days	Fair
Telone II (1,3-d)	6 gal	Fumigant—row	21 days	Excellent
Nimitz (Fluensulfone 40%)	3-7 pints/acre	Contact[d]	7 days	Fair

[a] Most nematicides can damage plants under certain conditions. Greenhouse-produced plants may be more sensitive to this type of injury.

[b] Control may be variable, and numerous galls may be found on roots later in the season.

[c] Apply 6 to 8 inches deep. Fumigants work best and cause the least injury when applied at soil temperatures above 50°F and when the soil is moist but not wet. Form a high, wide bed immediately after application.

[d] Contact nematicides vary in efficacy.

Target spot. Target spot (*Rhizoctonia* spp.) has been prevalent in North Carolina since 1984, especially in plant beds and greenhouses. In 1995, it caused the greatest losses of any disease since 1959. The fungus that causes target spot survives in many North Carolina soils. Saturated soils and leaf moisture favor sporulation of the fungus and germination of the spores into the tobacco leaves.

Target spot symptoms are similar to those of brown spot. With target spot, the centers of the lesions rapidly become very thin and shatter if only slight pressure is applied. Both brown spot and target spot are capable of forming concentric rings. Because target spot lesions are so fragile, the necrotic areas usually drop from the leaf, leaving a ragged appearance. Target spot may occur on leaves at any plant position and, where conditions favor the problem, may cause considerable destruction. Target spot, like brown spot, is favored by frequent rainfall and high humidity.

Removing the lower leaves and ensuring adequate nitrogen are recommended management tactics. In 2006, Quadris (Azoxystrobin) was registered for control of target spot. Quadris is a "locally systemic" product (i.e., it can move only a short distance from the point where a drop lands on a leaf). Therefore, drop nozzles are highly recommended for Quadris application in the field to ensure uniform coverage of the foliage. Other less mobile products are labeled, and may be used in rotation with Quadris.

Tobacco mosaic virus. Tobacco mosaic virus (TMV) is one of the most contagious tobacco diseases that growers encounter in North Carolina. The virus that causes it is large, and like all other viruses requires living tissue to multiply. Once a TMV particle enters the plant, it becomes a part of that plant and will persist in the plant tissue. The tobacco mosaic virus is spread in the sap of diseased plants. Anything that moves sap or fluids from a diseased plant to a healthy plant will move the virus. That includes machinery used during cultivation and the hands or

clothing of workers. It is not spread through air currents or by other carriers associated with most other diseases.

TMV is not as sensitive to weather conditions as most other tobacco diseases; however, it is easier for plants to become infected when there is moisture on them and they are succulent and growing rapidly. Damage is most severe when infected plants are infected during hot, dry conditions.

The most common symptom of TMV is leaf mottling, which is alternating areas of light and dark green tissue. This symptom is especially noted in the top of the plant or in younger tissue. During periods of high temperatures and high light intensity, affected portions of leaves may die, resulting in "mosaic burn."

Because of the virus's unique nature, control of TMV must be approached differently from that of other diseases. No chemicals are labeled for mosaic control, although the milk-dip treatment is beneficial as workers perform tasks within the crop. Resistant varieties are very valuable control tools (see Table 8-3).

Also, field rotations, clean equipment, and discarding of seedling trays (if TMV incidence was at least 20 percent by layby in any field) is important to manage TMV. In addition, greenhouse clippers, transplanters, tractor bottoms and tool bars, and any other equipment that came in direct contact with the foliage should be washed and sanitized with a 25 to 50 percent bleach solution.

Tomato spotted wilt virus. Tomato spotted wilt virus (TSWV) is a potentially devastating disease of tobacco in North Carolina. This virus also causes disease in North Carolina tomatoes, peppers, peanuts, and white potatoes. The host range is large, including many weeds and ornamentals. TSWV is moved from plant to plant by thrips. In most years, the tobacco thrips is the most important vector of TSWV early in the field season. However, the western flower thrips was abundant early in the 2002 season. In most years, this disease is damaging in the southern part of NC, this disease was widely found in the 2017 growing season. Mild winter conditions allow for thrips to increase in population and increase inoculum in winter weeds, leading to increased TSWV incidence in tobacco crops.

TSWV was first detected in North Carolina tobacco in 1989. Because the virus can infect more than four hundred species of plants, including many native and introduced plants found in North Carolina, it is established in the North Carolina agricultural landscape and is unlikely to be eradicated. Planning for TSWV management is crucial for growers in areas where the virus is firmly established; growers in other areas must remain vigilant in preventing the spread of the disease.

Symptoms of TSWV vary with plant age, virus strain, and environmental conditions. Newly transplanted seedlings die rapidly, then swiftly decay. As such, seedling infections are often misdiagnosed as other seedling diseases or transplanting problems. Plants that are ankle-high

and taller will show some characteristic foliar symptoms. On small plants, dark reddish-brown specks and leaf distortion are common on the youngest leaves. Slightly older plants will show classic reddish-brown necrotic spots or ringspots, often with star-like projections into the green leaf tissue. Necrosis of tissue running adjacent to leaf veins is common and characteristic. Despite the term wilt in the name, older plants only appear wilted because of the twisting and distortion the virus causes. Symptoms are usually most severe on one side of the plant and in the bud. Infected plants near flowering may have black streaks running down one side of the stem, often resembling burn from contact sucker chemicals. Streaks also occur within the pith. Plants that get infected near, during, or after flowering suffer little loss. Symptoms on these plants are generally local, being restricted to the leaf or leaves that were initially infected.

Although TSWV symptoms are somewhat characteristic, the disease can be confused with other viruses, especially tobacco streak virus (TSV). TSWV is usually randomly distributed throughout a field, whereas TSV is usually very concentrated near a particular field border. The only way to be sure which virus or viruses are present is to use a reliable assay procedure to identify the virus. Several plant species can be infected by TSWV; however, some are much better hosts than others. Research indicates that the most important sources for infection of tobacco are several species of winter weeds. Some of these include the annual smallflower buttercup, mouse ear chickweed, common chickweed, and spiny sowthistle, as well as the perennials dandelion and Rugel's plantain. As the winter annuals begin to die in the spring, adult thrips are forced to move to alternative plants, including tobacco. If the plant on which they developed was infected, they carry the virus with them. The virus can also move back and forth between winter annuals and summer annuals and perennials.

The movement of TSWV into tobacco is complex. Several things must happen for transmission to occur. First, there must be infected plant hosts in the area that harbor the disease, and these plants must also be hosts of one of the thrips species that can carry the disease. Second, these thrips must be one of the species that attack tobacco and adult thrips must move from the original host to tobacco. Finally, this movement must take place when the tobacco is in the field and susceptible to infection.

Several factors may influence the incidence of TSWV observed in the field:

- TSWV has gradually built up in weed hosts in North Carolina, which allows the movement of the virus over short distances.
- A relatively warm winter before the field season allows thrips to be active during much of the winter, spreading the disease among weed hosts, as well as increasing thrips survival and increasing their populations. Colder winters may suppress thrips populations and the spread of the disease among weeds, resulting in a smaller inoculum source in the spring.
- An early, dry spring causes winter hosts to yellow and die earlier than usual. Thrips begin moving off these dying weeds at the time that tobacco is being transplanted. Generally, tobacco seems to be most susceptible to infection at transplanting. As the crop ages, it is

progressively less likely to be infected by a virus-carrying thrips. If winter weeds remain green and healthy until well after tobacco is in the field, thrips have less need to move to newly set tobacco.

While no current management practices will completely control the effects of TSWV on tobacco crops, some tools that can help moderate the disease have emerged in the last few years. Proper application of these strategies can significantly reduce TSWV incidence in tobacco fields, but they may not provide adequate suppression under extremely high virus pressure. See chapter 9, "Tobacco Insect Management," for more information.

Thrips can transmit TSWV very quickly, and most of these virus-carrying thrips come from outside the tobacco field. Overtop insecticides do not kill these thrips quickly enough to stop the spread of the virus. This type of spraying has not been successful in reducing disease incidence, though some disease suppression has been noted on Admire-treated plants in Georgia and North Carolina. Applying Admire in the greenhouse to control aphids and other insect pests may help suppress TSWV (Table 8-6).

Table 8-6. Suppression of TSWV with Actigard and Admire Pro, North Carolina

	Percentages of Plants Infected by Tomato Spotted Wilt Virus			
County, Year	**Untreated Control**	**Admire Pro 0.8 oz/ 1,000 Plants**	**Admire Pro 0.8 oz/1,000 Plants + Actigard 10 ppm float water**	**Admire Pro 0.8 oz/1,000 Plants + Actigard 1 oz/50,000 Plants**
Duplin, 2008	38	10	4	4
Craven, 2008	20	11	5	3
Duplin, 2005	54	36	22	36
Onslow, 2005	29	20	9	12
Average	35.3	19	10	14

Note: The Actigard and Admire Pro treatments were applied in the greenhouse 7 to 14 days before transplanting. Actigard was applied to trays as a foliar spray and then drenched with a sufficient amount of water to move the material to the root zone, or it was applied in the water bed followed by thorough circulation of the water in the bed to ensure uniform distribution of the material.

The application of Actigard, alone or in combination with Admire or Platinum, to seedlings in the greenhouse shows promise for being an effective and economical management tactic. Most economically important TSWV infections apparently occur within the first week or two after transplanting; many may occur during the first few days. Thus, protection should be in place before transplanting. Application of any chemicals after the virus has infected the plant will be of little, if any, benefit.

Treatment in the greenhouse with Actigard and higher rates of Admire may result in early season leaf damage and stunting and that this effect is greatest when both materials are used. This is usually a temporary effect and has not resulted in significant loss of yield; however, such losses are possible. For that reason, use both chemicals only when at least 10 percent losses from

TSWV have been observed in the past. Where TSWV levels have been significant but lower, Admire alone is recommended at 0.8 to 1.2 ounces per thousand plants (Admire 2F at 1.8 oz/thousand plants) in the greenhouse. Lower rates of Admire are adequate if only insect control is needed.

Read the label to determine the appropriate rate before treating plants. Injury is most likely when plants are stressed. If Actigard is used, take great care in ensuring that the product is precisely measured and applied according to label directions. Actigard can be applied as a foliar spray and then drenched to the root zone with water or applied in the float bed water. If application in the float bed water is chosen, use Table 8-7 to calculate the quantity needed. Platinum used alone in the greenhouse at 1.3 ounces per thousand plants has not reduced TSWV significantly; however, the combination of Platinum and Actigard has been as effective as the combination of Admire and Actigard.

Table 8-7. Conversion of ppm to grams of Actigard based on float bed size

Gallons per Bed	Actigard Rate (ppm)			
	10.0	**15.0**	**20.0**	**25.0**
3,000	4.0 g	6.0 g	7.9 g	9.9 g
3,200	4.2 g	6.4 g	8.5 g	10.6 g
3,400	4.5 g	6.8 g	9.0 g	11.3 g
3,600	4.8 g	7.2 g	9.5 g	11.9 g
3,800	5.0 g	7.6 g	10.1 g	12.6 g
4,000	5.3 g	7.9 g	10.6 g	13.2 g
4,200	5.6 g	8.3 g	11.1 g	13.9 g

Note: ppm = parts per million.
HOW TO READ THE TABLE: If a bed has 3,000 gal of water and you wish to apply 15 ppm of Actigard, then this is equivalent to 6 grams of the product.
This table shows the rate of Actigard product (in grams) to add to obtain the desired ppm rate.
Use the lower rate (10 ppm) in areas of moderate TSWV risk and the highest rate (25 ppm) in areas of severe TSWV risk. A waiver of liability must be signed to obtain an Actigard label. To obtain this waiver and label, growers must visit www.farmassist.com and register (email address required).
Apply Actigard three to five days before transplanting. For best results, dilute the Actigard in a small volume of water, and then add this volume to the float water. Ensure adequate and uniform circulation of the product within the bed.

Weather fleck. Weather fleck is not an infectious disease, but it causes dark, metallic-like, sunken leaf spots (flecks) that gradually fade to white with age. Symptoms are most obvious on older leaves of young plants or on middle-aged leaves of older plants. Spots are often more common near leaf tips. Damage can be severe enough to blight bottom leaves. Weather fleck is an injury caused by the common air pollutant ozone. Ozone is heavy oxygen (O_3) and is produced by internal combustion engines and by certain manufacturing processes. During periods of cloudy, overcast, or rainy weather, the concentration of ozone that would normally escape into the stratosphere is held closer to ground level. During these conditions, leaf pores (stomata) remain open the longest and the leaves absorb the most ozone. Some varieties are much less

sensitive to weather fleck than others, and growers who experience chronic difficulty should select a variety that is more tolerant.

TIPS ON PLANNING DISEASE MANAGEMENT

No single practice can be expected to provide protection from the many different diseases that might attack tobacco during a growing season. A "tobacco disease map" of each field is of great benefit. To develop such a map, sketch the field and mark areas of disease infestation. Update the map each time tobacco is in the field, noting any change in location and in level of infestation. Over time, growers who do this can plan adequate control practices from season to season. For black shank and Granville wilt, the average percentage of plants diseased within a field gives a good indication of the level of that disease in the field.

OTHER REFERENCES

Tobacco disease information notes are available from https://tobacco.ces.ncsu.edu/tobacco-pest-management-diseases/

Compendium of Tobacco Diseases is available from the American Phytopathological Society. Find more information at http://www.apsnet.org/apsstore/shopapspress/Pages/41175.aspx.

Tobacco Diseases (http://tobacco-diseases.info/) is a website developed by Dr. David Shew (NC State University) that describes more about common tobacco pathogens.

A PRECAUTIONARY STATEMENT ON PESTICIDES

Pesticides must be used carefully to protect against human injury and harm to the environment. When possible, use different modes of action when repeated application of pesticides is necessary for controlling disease. Accurately diagnose pest problems and select the proper pesticide if one is needed. Follow label-use directions, and obey all federal, state, and local pesticide laws and regulations.

Table 8-8. Condensed management guide for seedlings (for more information, contact your county Cooperative Extension center)

Disease	Cultural Management	Chemicals (read and follow the label)	Comments
Anthracnose (*Collectotricum gloeosporioides*)	Clip beds frequently to allow foliage to dry.	Dithane Rainshield (mancozeb) Greenhouse 0.5 lb/100 gal (sprayed)	Spray foliage to runoff, and maintain thorough coverage with fungicide when weather is cool and damp. Fungicide may be sprayed twice a week.
Blue mold (*Peronospora tabacina*)	Clip beds frequently to allow foliage to dry.	See Anthracnose Aliette WDG 0.5lb/50 gal water	Spray Dithane Rainshield weekly from the time plants are the size of a quarter. Apply preventively or at the first sign of blue mold. Do not exceed 2 applications.
Collar rot (*Sclerotinia sclerotiorum*)	Don't seed more than 60 days before plants are needed. Thoroughly ventilate and use air-circulating fans. Do not dump soil or plants near greenhouses. Reduce the amount of debris left on seedling beds after clipping.	None	
Damping-off (*Pythium* spp.)	Plant bed: Select warm, well-drained site. In greenhouses, keep pH below 6.2. Place trays in float beds as soon after filling with water as possible.	Terramaster (etridiazole) 35W 2 oz/100 gal float water Terramaster (etridiazole) 4E 1.4 fl oz/100 gal float water	Thoroughly mix into float water 2 to 3 weeks after seeding.
Soilborne diseases (Root-knot, Granville wilt, black shank, some damping-off)	Plant bed: Select warm, well-drained site. Greenhouse trays: Wash trays. Steam at 160°F–175°F for 30 min.	Nematodes: Telone II 6 gal/acre Disease: Chloropicrin 3 gal/acre Pic + 4 gal/acre	Thoroughly prepare bed. Fumigate if temperature is higher than 50°F and soil is moist but not wet. Wait 24 to 48 hours after cover removal before seeding.
Target spot (*Rhizoctonia* sp.)	Clip plants frequently to allow foliage to dry.	Quadris 0.14 ml/100 sq ft	See "Blue mold." Make only one application prior to transplant.
Tobacco Mosaic Virus	Do not touch plants. Use new trays if previous seedlings were infected. Control horsenettle around seedlings. Keep tomato and pepper plants and fruits out of area.	Household bleach Milk (any type) 5 gal/1,000 sq ft of bed or 5 lb dry skim milk in 5 gal water/1,000 sq ft	Wash and sanitize mower with 25 to 50 percent household bleach and/or steam clean mower. Spray plants within 24 hours of transplanting.

Table 8-8. *(continued)*

Disease	Cultural Management	Chemicals (read and follow the label)	Comments
Angular leafspot (*Pseudomonas syringae*)	If disease is severe, avoid working in fields when foliage is wet.	None	Control is not usually necessary.
Barn rot (*Erwinia* sp.)	Harvest tobacco dry. For wet tobacco, run fans for 24 hours with vents open to dry tobacco before increasing temperature.	None	
Black root rot (*Thielaviopsis basicola*)	Rotate (Table 8-1). Maintain soil pH near 6.0.	Chloropicrin at 3 gal/acre Pic + at 4 gal/acre	Observe 21-day waiting period between application and transplanting.

Table. 8-9. Condensed management guide for field diseases (for more information, contact your county N.C. Cooperative Extension center)

Disease	Cultural Management	Chemicals (read and follow the label)	Comments
Black shank (*Phytophthora nicotianae*)	Rotate (Table 8-1). Use resistant varieties (Table 8-3). Destroy stalks and roots (Table 8-2). Plant on high, wide bed. Cultivate infested fields last. Manage nematodes.	Ridomil Gold EC , LS (WSP) at 1+.5 pt (lb)/acre 1+1 pt (lb)/acre 1+1+1 pt (lb)/acre Ultra Flourish (2x Ridomil Gold rates) Ridomil Gold, 1 pt (lb)/acre + Chloropicrin at 3 gal/acre Ridomil Gold, 1 pt (lb)/acre + Pic + at 4 gal/acre Presidio at 4 fl oz/acre Orondis Gold (see label for rates)	In fields with histories of black shank, use all cultural practices. Use Ridomil just before transplanting. Apply again at first cultivation and/or lay-by if risk of disease is high. Ultra Flourish 2E brand of mefenoxam used at 2 times the rates of Ridomil may be used in place of Ridomil Gold 4EC brand of mefenoxam. When using a fumigant apply mefenoxam at first cultivation, not preplant. See Table 8-4. Soil directed spray. Greatest level of control when used in transplant water.

Table. 8-9. *(continued)*

Disease	Cultural Management	Chemicals (read and follow the label)	Comments
Blue mold (*Peronospora tabacina*)	Destroy unused seedlings as soon as possible. Avoid planting in shaded areas. Avoid close plant spacings.	Acrobat 50WP at 2.5 lb/100 gal Actigard 50W at 0.5 oz/a in 20 gal water Dithane Rainshield at 1.5–2 lb/100 gal Aliette WDP at 2.5 – 4 lb/acre Quadris at 6–12 fluid oz/acre Revus at 8 fluid oz/acre Presidio at 4 fl oz/acre	Spray at first threat of blue mold and every 7–10 days. See label for spray volumes. Apply after plants are 18 in. tall. Repeat in 10 days. See label for precautions. Spray foliage weekly for complete coverage. Stop spraying all products 21 days before harvest. Apply preventively or at first sign of blue mold. Apply until 3 days before harvest See label for spray volumes. Do not apply within 7 days before harvest. See label for spray volumes.
Brown spot (*Alternaria alternata*)	Avoid close plant spacing. Control suckers. Avoid excess nitrogen. Control nematodes. Use tolerant varieties.	None	Harvest as often as necessary to save tobacco.
Charcoal rot (*Macrophomina phaseolina*)	Avoid overapplication of contact sucker chemicals.	None	Rare, but occurs during hot and dry periods.
Etch Tobacco Etch Virus		None	No control available.
Fusarium wilt (*Fusarium oxysporum* f. sp. *nicotianae*)	Rotate. Destroy stalks and roots. Avoid root wounding. Use resistant varieties. Control nematodes.	None	Significant problem only when root-knot or root injury is present.
Granville wilt (*Ralstonia solanacearum*)	Rotate (Table 8-1). Destroy stalks and roots (Table 8-2). Use resistant varieties (Table 8-3). (All varieties may be severely damaged.) Avoid root wounding. Plant on high, wide bed. Manage nematodes.	Chloropicrin at 3 gal/acre Pic + at 4 gal/acre	Use all cultural practices and a fumigant (fall or spring) where Granville wilt has recently occurred. Observe 21-day waiting period for fumigants. Use higher rates for broadcast application.

Table. 8-9. *(continued)*

Disease	Cultural Management	Chemicals (read and follow the label)	Comments
Hollow stalk (Bacterial soft rot) (*Erwinia* sp.)	Avoid getting soil on hands or stalks while topping and suckering.	None	
Lesion nematodes (*Pratylenchlus* spp.)	Destroy stalks and roots (Table 8-2). Rotate with fescue.	None usually required. See Table 8-7.	Not a problem year after year.
PVY (vein-banding) (Potato Virus Y)	Avoid transplants from areas with high incidence of PVY.	None	No practical control.
Ringspot (Tobacco ringspot virus)	Avoid problem fields.	None	No remedial control.
Root-knot (*Meloidogyne incognita*) (*M. arenaria*) (*M. javanica*) (*M. hapla*)	Destroy stalks and roots (Table 8-2). Rotate (Table 8-1). Use resistant varieties (Table 8-3). Take and submit fall nematode samples.	For nematicides see Table 8-7.	Rotation usually requires two or more years. Resistant varieties are resistant only to races I and 3 of *M. incognita*. Other species and races are now common in North Carolina. Observe 21-day waiting period for fumigants.
Soreshin (*Rhizoctonia* sp.)	Pull and handle plants carefully to avoid wounding or bruising.	None	Plant on high, wide bed to provide adequate drainage. Avoid placing nitrogen too close to stalk.
Southern stem rot (*Sclerotium rolfsii*)	Avoid wounding stalk.	None	
Target spot (*Rhizoctonia* sp.)	Harvest or remove bottom leaves as soon after disease begins as possible. Maintain recommended nitrogen levels. Maintain sucker and weed control.	Quadris at 6–12 fluid oz/acre (8 fl oz/acre has given consistently good results)	Easily confused with brown spot.
Tobacco cyst (Osborne's cyst) (*Globodera tabacum*)	Rotate (avoid tomato and pepper). Destroy stalks and roots (Table 8-2).	Telone II at 6 gal/acre	

Table. 8-9. *(continued)*

Disease	Cultural Management	Chemicals (read and follow the label)	Comments
Tobacco mosaic virus (Field)	Do not plant infected seedlings. Rotate (Table 8-1). Destroy stalks and roots (Table 8-2). Use resistant varieties (Table 8-3). Practice good sanitation. Manage horsenettle. Irrigate during dry periods.	None	Wash hands with soap or milk after handling tobacco. Disinfect equipment with 25 to 50 percent household bleach.
Tomato spotted wilt virus	Avoid destruction of winter weeds. Avoid planting during peak thrips flights.		
Weather fleck (Ozone air pollution)	None	None	No practical control.

9. TOBACCO INSECT MANAGEMENT

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Insect populations were low and unremarkable during 2019. Following high incidence of Tomato Spotted Wilt Virus (TSWV) throughout eastern North Carolina in 2017 and 2018, TSWV occurrence was very low this year. This likely due to both a cold winter and rain in some locations during the transplant period, which can depress virus infection in winter weeds and limit thrips movement in spring, respectively. Thrips flight timing did occur when predicted by population models, and these models remain valuable tools for timing treatments in high risk areas. The online tool powered by our thrips flight model was updated during the 2019 growing season and can be viewed at http://climate.ncsu.edu/thrips.

Tobacco budworms appeared to only have one generation that affected tobacco pre topping during the 2019 season. Budworms and earworms were a significant issue during the late summer and early fall for industrial hemp, where they appear to be the most significant pest at this time.

We had an isolated and unusually high pre-topping hornworm population at the Upper Coastal Plain Research Station near Rocky Mount, but we did not receive similar reports from growers elsewhere.

We are in the process of developing new scouting recommendations that are more sensitive to modern production practices. However, our current recommendations are still effective and reliably result in more appropriately timed insecticide treatments that protect yield, minimize cost, and reduce pesticide residues. We strongly encourage growers to use these thresholds to time treatments on a field-by-field basis. Additional information on insect pest biology, along with images of pests and their damage can be found at tobacco.ces.ncsu.edu.

PROTECTING SEEDLINGS IN GREENHOUSES

Insects seldom threaten to destroy all the plants in a greenhouse, but they can reduce the number of usable plants produced. Insect pests may also be moved from the greenhouse to the field, where they are more challenging to control. The most common greenhouse pests are crickets and aphids, but ants, slugs, and other occasional pests may be present. Greenhouse insect management requires a systematic approach that starts with careful planning and close observation.

Sanitation

Sanitation in and around greenhouses is essential. Keep houses free of trash, supplies, equipment, or other unnecessary items. Insects and other pests can hide in or feed on materials in the greenhouse. A strip of bare ground, sand, or gravel around the house may help reduce the number of insect pests entering the house. Once transplanting is complete, remove and destroy excess plants in the greenhouse as soon as practical. Otherwise, they can serve as a nursery for pests moving into fields.

Fallow Periods

If possible, use greenhouses only for tobacco production. Growing other plants, such as ornamentals or vegetable seedlings, can introduce or sustain insect pests. Some of these may be uncommon tobacco pests for which no labeled pesticides are available or that are very difficult to control. If greenhouses are used for other purposes, they should be kept empty (fallow) whenever possible. A long empty period just before introduction of tobacco is especially important in breaking the life cycle of pests. Growing other plants in the greenhouse from seed is preferable to bringing in seedlings from another location. The latter practice increases the chance of introducing pest problems.

Cold

Keeping the empty greenhouse open during cold periods helps reduce populations of insects wintering inside. Do not leave any materials (such as trays) in the greenhouse to provide pests insulation.

Solarization

Closing the greenhouse during the summer and bringing the temperature up to 140°F (but not higher) for several days may also help reduce insect numbers. Again, you should remove any insulating material (such as trays) that protect insects. Also remove any materials that can be damaged by high temperatures.

Insecticides

Watch plants carefully and treat with an insecticide if insects threaten an adequate supply of healthy plants. Few insecticides are labeled for use in tobacco greenhouses. Acephate is one of the few broad spectrum materials available for pest management in tobacco greenhouses. Acephate 97UP can be used at ¾ tablespoon per 3 gallons of water for each 1,000 square feet (Acephate 75 EP at 1 tablespoon). Uniform coverage is important. Check your nozzle spacing and be sure the nozzles are not worn or damaged. A spray table should be used to check for unevenness in your spray pattern on an annual basis. Several other insecticides are labeled for use around the outside of structures or within the greenhouse on crops other than tobacco. Check with your N.C. Cooperative Extension county agent or the *North Carolina Agricultural Chemicals Manual* for specific recommendations.

A metaldehyde bait (Deadline Bullets) is labeled for control of slugs in tobacco greenhouses, and Sluggo (iron phosphate) baits are organically acceptable (i.e., Organic Materials Review Institute [OMRI]-listed). To avoid injury, do not put baits directly on plants.

Fire ants can carry off seeds and germinating plants from large areas of a house and may be problematic in warm springs. These pests should be controlled before seeding by using an insecticide bait. Baits may act more slowly than other pesticides, so start bait use early. Extinguish is a fire ant bait that is also labeled for use on cropland. Bait treatments typically provide longer-acting control than mound drenches with insecticides like acephate, although these two methods can be combined by first treating with a bait and then applying a drench treatment a few days later.

PROTECTING TOBACCO IN THE FIELD

Management of Soil Insects

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

It is not possible to control wireworms in tobacco with post transplant rescue treatments; you must decide in advance whether you need to use soil-applied insecticides (Table 9-1). If there is a history of wireworms, if the field was weedy or fallow, or if the field is heavily infested with soilborne diseases such as black shank and Granville wilt, a preventive treatment may be justified. In other cases, preventative management is not recommended. Insurance treatments for wireworms add to the costs of production and add pesticides to the environment.

Either contact insecticides (Lorsban/Warhawk, Capture) or systemic insecticides (Admire, Platinum, Brigadier) can be used for wireworm control. Both types have provided good control in tests, but systemic materials also provide control of aphids and flea beetles. Use either a contact or a systemic insecticide for wireworms, not both. Whether you choose a contact or a systemic, the following application techniques are important:

- Broadcast materials should be thoroughly incorporated into the soil. (This usually requires two passes with incorporation equipment.) It is also important to give broadcast insecticides time to work before transplanting; at least two weeks are recommended, unless the label says otherwise.
- For systemic greenhouse-applied insecticides, apply materials evenly and wash them off thoroughly to move the insecticide to the potting soil.

- Transplant water treatments should only be applied if application equipment can be accurately calibrated. Pressurized tanks fitted with nozzles to apply transplant water treatments are advised, and growers are cautioned not to apply transplant water treatments using gravity flow tanks.

When choosing soil-applied insecticides, always consider the possible effect on groundwater and surface water. See chapter 11, "Protecting People and the Environment When Using Pesticides," for information on leaching and runoff potentials.

Table 9-1. Selected soil-applied insecticides for wireworm control

Insecticide and Formulation	Amount/Acre	Remarks
Lorsban Advanced	2 qt	Apply prior to transplant and cultivate into the top 6 in. of soil.
Capture LFR[a]	3.4–6.8 fl oz	Apply at transplant in transplant water or incorporate pretransplant into the top 6 in. of soil.
Brigadier[a,b]	3.8–6.8 fl oz	Apply in transplant water.
Admire Pro	1.2 fl oz per 1,000 plants	Apply to plants in greenhouse followed by immediate wash-off, OR apply in transplant water. Note that wireworm rates are higher than aphid and flea beetle rates. Only use wireworm rates in fields with history of wireworm injury.
Platinum 75SG	0.43 oz per 1,000 plants	
Platinum 75SG	1.3 fl oz per 1,000 plants	

[a] Capture LFR and Brigadier wireworm control data are limited.
[b] Brigadier is a combination of bifenthrin, a pyrethroid, and imidacloprid.

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

Treat with a foliar spray (Table 9-5) if 5 percent or more of the plants are damaged and live caterpillars are observed. Stand losses below 10 percent will not reduce yields. Fields are more likely to be infested if they were weedy the previous fall and winter or if they are low-lying with heavier soils.

Other pests. Growers may have occasional problems with sod webworms. These caterpillars tunnel in the underground stem much like wireworms, but they are almost always found in the aboveground stem, and they line the cavity with silk. These strands of silk, covered by dirt particles, often hang out of the entry hole. Problems with webworms are rare but sometimes

occur in fields recently converted from sod. Other uncommon soil pests are white-fringed beetles and vegetable weevils. The white-fringed beetle is an introduced pest whose larvae (grubs) are white or cream colored and C shaped. The grub has no legs, but it does have a distinct head capsule. Damage is similar to that of wireworms but can be more severe. Vegetable weevil larvae may feed on tobacco seedlings and are light green legless grubs. Adult vegetable weevils may also feed on tobacco leaves following transplant and are grey-brown with a v-shaped mark on their wings. Soil-dwelling pests can be controlled after transplant, but growers should note fields where damage has occurred to develop preventative management strategies the next time they plant tobacco.

General Steps in Managing Leaf-Feeding Insects

The goal of insect management is not to kill insects but to reduce damage and maximize profits. Thus, it is not only necessary to protect the crop but also to keep the costs of protection as low as is practical. Growers should consider environmental impact, worker health, and pesticide residue risk when determining if an insecticide application is necessary and selecting the best material. Growers stand the best chance of meeting these goals by combining a variety of tools. There are four basic control strategies that are used against insects in tobacco: (1) cultural control, (2) biological control through conservation of beneficial insects, (3) preventive insecticide treatments applied to the soil, and (4) insecticides applied after a problem develops (remedial treatment). Calendar-based, over-the-top spray schedules add costs and often lead to more problems than they control. They should be avoided.

Cultural control. Cultural control practices are non-insecticide strategies that reduce insect damage. These include production practices that may seem unrelated to insects, such as planting date, variety selection, and nutrient management. These and other practices may significantly influence insect populations and reduce the numbers of an insect pests in a wide area, make individual fields less attractive to insects, or help the plant tolerate insect attack with less loss. Because these practices are also important in good crop management, most add little or nothing to the cost of production.

- **Transplant production:** Destroy overwintering sites and hosts of aphids and flea beetles near greenhouses or plant beds (garden greens, wild mustard, dock). Destroy unused plants as soon as transplanting is complete. Plants left intact may become breeding sites for several insect pests and sources for diseases such as blue mold.
- **Transplant timing:** Early planting reduces the chance of hornworm problems, early or late-planted tobacco generally has fewer aphids, and late planting reduces budworm numbers. However, late-planted tobacco usually yields less.
- **Weed management:** If you are in a high risk area for tomato spotted wilt virus (TSWV), practice weed control at least two weeks prior to transplant to prevent flushing thrips into a susceptible tobacco crop. Encouraging grassy vegetation surrounding fields can also minimize thrips habitat. Grasses are poor hosts for TSWV and do not support vector

species of thrips. To reduce grasshopper and cricket invasion, keep borders clean and avoid haying grasshopper-infested grass strips near tobacco.

- **Nutrient management:** Do not use nitrogen at rates higher than those recommended by field specific soil test results. Aphids, budworms, and hornworms are attracted to plants high in nitrogen.
- **Topping and sucker control:** Top at 50 percent early button. Timely topping and good sucker control reduces the attractiveness of the crop to budworms, hornworms, and aphids.
- **Post harvest:** Destroy stalks and roots immediately after harvest to reduce pest overwintering sites. This is important for budworms, hornworms, tobacco splitworm, and flea beetle management. It is also very important in control of diseases.

Biological control. Biological control is the use of a living organism to control another living organism. In general, this includes nematodes, pathogens, predators, and parasites. There are no commercially available biological control agents that are effective against insect pests in tobacco, so we rely on the many naturally occurring predators and parasites for biological control. The importance of these beneficial organisms in controlling insect pests is hard to exaggerate. For example, together parasitic wasps, predatory stilt bugs, and other beneficial insects can kill 80 to 90 percent of budworms and hornworms in a field. To make the most use of this free, natural control, follow these practices:

- **Insecticide selection:** Minimize or avoid using systemic insecticides that may reduce the populations of beneficial insects. If insecticide is necessary, choose the one most likely to target the pest and not harm beneficial insects. One way to tell if a pesticide is likely to harm beneficial insects is to compare the number of pest groups on the label. An insecticide that kills beetles, caterpillars, and flies is more likely to be harmful to beneficial insects than one that only kills caterpillars. Avoid IRAC (Insecticide Resistance Action Committee) MOAs (modes of action) 1 and 3, when possible; these are broad-spectrum materials. Laboratory assays have demonstrated that acephate (IRAC 1A), bifenthrin (IRAC 3), and pyrethrins (IRAC 3) are all highly toxic to stilt bugs, the most common predatory insect in tobacco fields.
- **Insecticide timing:** Only use insecticides after transplant when pests exceed economic thresholds (see below). Most insecticides also reduce the number of predators and parasites in a field.

Table 9-2. Effectiveness of soil-applied insecticides

Material	Wireworm	Aphid	Flea Beetle[a]	TSWV Suppresion[b]
Admire and generic imidacloprids	Intermediate	Best	Best	Best
Lorsban	Intermediate	No	No	No
Orthene (TPW)	No	Inconsistent	Best	No
Platinum	Intermediate	Best	Best	Intermediate
Verimark	No	Intermediate	Best	Intermediate

Note: No = Not recommended.

[a] Ratings for flea beetle control are for early season populations.

[b] Imidacloprid suppresses TSWV by altering thrips feeding behavior.

Preventively applied soil insecticides. Systemic insecticides are applied to the soil and taken up by the plant to control leaf-feeding insects. Systemics that control aphids and flea beetles and suppress TSWV are available (Table 9-2). There are several reasons you might use one of these materials. They offer some insurance against loss to insect pests and against the need to apply rescue treatments. They may slow the development of aphid populations and provide more time to detect and react to this pest. They may also do other things besides control leaf-feeding insects—for example, they may control nematodes or wireworms or reduce tomato spotted wilt infection—and this may increase yield or quality even when leaf-feeding insects are absent.

However, each year many untreated fields never reach threshold for the pests controlled by a systemic insecticide (e.g., aphids and flea beetles). In those cases, treatment was an unneeded expense. In addition to not always being necessary, use of systemic insecticides may have other disadvantages. Most systemics offer protection against only one or two pests (usually aphids and early season flea beetles). These insecticides will not reduce budworm and hornworm numbers and sometimes may actually increase them. Protection is not always season-long, and it may not be adequate to keep pests from reaching damaging levels. Some systemics may reduce the numbers of beneficial insects in the field and may actually increase pest pressures. There is always a risk that a systemic will injure tobacco and reduce yield or quality. There have been concerns about the effect of some materials in particular, listed in Table 9-3, on plants post transplant. However, in most cases, post-transplant plant stunting due to insecticides in transient and is not apparent post topping.

There is no advantage in using two chemicals that do similar jobs, and the likelihood of crop damage is increased. Combining systemic insecticides is not recommended.

All pesticides pose some risk to humans and the environment. The public is concerned about pesticide use in their communities and on the commodities they buy, and as with any pesticide, widespread use of systemics over time may result in the development of resistance.

There is one systemic insecticide that may have activity against early season tobacco budworms and hornworms. Coragen (chlorantraniliprole) is labeled for application in transplant

water against pre-topping caterpillar pests. In most cases, these are tobacco budworms, but hornworms can also occur pre topping. NC State field trials show that transplant water applications can have some efficacy against tobacco budworms very early in the season (four to six weeks post transplant), although longer activity has been observed against hornworms. Hornworms are infrequent pre-topping pests and are easily controlled with other materials, so a preventive treatment targeted toward them is not advised. Growers who are interested in using Coragen in a transplant water application should carefully follow the label, use at least one hundred gallons of water per acre, and use equipment that ensures that each plant receives the correct rate of pesticide in the appropriate amount of water.

Foliar applied remedial insecticides. To determine if any insect pest population requires remedial treatment, you must know the pest level in each field. To get this information, scout fields weekly. To scout small fields (less than 10 acres), make 8 stops, randomly distributed throughout the field. At each stop, check five plants in a row for insects for a total of 40 plants observed in small fields. In fields larger than 10 acres, add 2 stops for each 5 acres. For fields greater than 20 acres, make 20 stops. The exact pattern of stops is not critical, but be sure your path covers all parts of the field. You should not take samples near field borders (within 30 feet) because pests are often more numerous there.

Do not bias your sample by stopping to count when you see a damaged plant. Instead, determine where you will stop before you get there. Count the number of hornworms, budworms, and aphid- infested plants, and estimate the number of flea beetles per plant. Also note any other insects or damage. It is possible to reduce profits by applying insecticides that are not needed. The point at which it pays to treat is called an economic threshold.

Consider each production unit (farm or field) independently, as pest populations will differ between fields. Do not treat all fields based on the pest population in one or two locations.

Scouting is your insurance against pest damage, and it should be done on a regular basis. If you think a field may soon reach the threshold level for a pest (for example, if you find many newly hatched hornworms less than 1 inch long or many small aphid colonies), check the field again in two to three days. It is better to check again than to treat below threshold because beneficial insects and weather may eliminate the problem. For example, young hornworm larvae are easily washed from plants during rainstorms or killed by predators.

When you leave the field, compare your results with the treatment thresholds that have been established for each pest (Table 9-4) to determine whether you should initiate remedial treatment.

These thresholds were developed as guidelines for average conditions. In unusual situations (drought stress or multiple pests), use your judgment in applying thresholds. Also keep in mind that thresholds were developed based on relatively high-priced tobacco. When the value of the crop goes down, the point at which it pays you to begin control goes up. Thus, the same thresholds are even more conservative now than in the past.

Table 9-3. Post transplant impacts of systemic neonicotinoid insecticides, summarized data from field trials, 2009-2013

			Leaf Width—3 weeks after transplant		
Treatment	**Rate/ 1,000 plants**	**Total number of trials**	**Number of trials where treated plants had smaller leaves than untreated plants**	**Number of trials where treated plants had equal to or larger leaves than untreated plants**	**Average proportion of treated leaf width relative to untreated leaf width[a]**
Admire Pro 4.6F	0.6 fl oz	5	1	4	1.00
	1.2 fl oz	2	1	1	0.75
Platinum 2SG	0.5 fl oz	1	0	1	1.01
	1.3 fl oz	1	0	1	1.18
	2.6 fl oz	1	0	1	0.94
Platinum 75SG	0.85 fl oz	1	1	0	0.76

[a] 1.0 means leaves were the same size. Less than 1.0 means treated leaves are smaller. Greater than 1.0 means treated leaves are larger.

Table 9-4. Economic thresholds for key tobacco insect pests. Based on a minimum of 40 plants randomly sampled per field (for fields less than 3 acres)

Insect Pest	**Scouting Period**	**Economic Threshold**
Tobacco budworms	Before button	10% infested plants. Do not count damaged plants as infested!
Tobacco/tomato hornworms	All season	1 or more larvae at least 1 inch long per 10 plants; parasitized larvae count as 1/5 of larva[a]
Flea beetles	Post transplant	4 or more beetles per plant
	Preharvest and harvest	60 or more beetles per plant
Aphids	Pre topping	10% of plants with 50 or more aphids on upper leaves
Japanese beetles, loopers, grasshoppers	All season	10% damaged plants with live insects active in fields (note that this threshold is a suggestion and is not based on research)
Cutworms, vegetable weevils, mole crickets, slugs	Post transplant	5% or more small plants are killed or injured
Tobacco splitworm	Post topping	10% or more of plants with greater than 10 mines per plant (note that this threshold is under development)

[a] Data from 37 locations collected from 2010 to 2016 suggest that hornworm populations exceed this threshold 51 percent of the time, meaning they did not exceed threshold 49 percent of the time. Therefore, preventative treatments against hornworms, such as those in tank mixes with contact applications, are not recommended.

When choosing an insecticide, remember that no single insecticide is best for all pests or even for a single pest under all conditions. Choose an insecticide that fits your conditions and needs when the pest problem occurs. To make this choice, ask yourself the following questions:

What insect pest or pests need to be controlled? To do a good job of management, you must know which pests are in your fields. This is achieved through regular scouting and correct pest identification.

What are the most effective insecticides to use against the pest or pests you are trying to control? If two or more insects are damaging a field, the best choice would be an insecticide providing good control of all the pest insects. This does not mean you should always look for broad-spectrum insecticides. Narrowly targeted materials, which are usually less detrimental to beneficials and the environment, often are the best choice. Table 9-5 shows the effectiveness of insecticide sprays against major leaf-feeding insects, and Table 9-7 shows general insecticide recommendations.

What are the hazards to the applicator and other workers? When choosing pesticides, consider the hazard presented by each and the abilities of the person doing the application. It is best to use less hazardous materials when workers will be entering fields frequently. Labeling regulations require that all pesticides bear signal words to indicate relative hazards of use. Products bearing the words Danger—Poison are highly hazardous, those bearing Warning are moderately hazardous, and those bearing Caution range from slightly hazardous to relatively hazardless. You also need to consider the protective equipment requirements imposed by worker protection standards (see chapter 11, "Protecting People and the Environment When Using Pesticides").

What are the hazards to groundwater and surface water? Insecticides vary in their potential for leaching into groundwater or running off in surface water. If your farm has leachable soils or fields with high runoff potentials, you should choose remedial (and soil-applied) chemicals carefully (see chapter 11, "Protecting People and the Environment When Using Pesticides").

Table 9-5. Effectiveness recommended of foliar insecticides against insect pests

Insecticide	Insect Pest Control Levels			
	Aphid[a]	**Budworm**	**Flea Beetle**	**Hornworm**
Actara	Excellent	No	Excellent	No
Admire Pro	Excellent	No	Excellent	No
Assail[b]	Excellent	No	Excellent	NR
Brigade[e]	No	Good	No	NR
B. thuringiensis	No	Moderate[c,d]	No	Excellent
Coragen	No	Good	No	Excellent
Denim	No	Good	No	Excellent
Fulfill	Excellent	No	No	No
Orthene[e]	Good	Moderate[e]	Good	Excellent
Blackhawk	No	Good	No	Excellent
Warrior[e]	Fair	Good[e]	No	Excellent

Note: Moderate also means the insecticide may be less consistent.
NR = Not recommended or too limited data to recommend.
[a] Aphid control ratings are based on maximum labeled rates.
[b] Aphid rating for Assail is based on limited data. Assail acts an ovicide for tobacco budworm.
[c] *B. thuringiensis* is sold under a variety of trade names.
[d] *B. thuringiensis* products seem to be more effective against budworms later in the season.
[e] There are residue concerns associated with these materials. Check with your purchaser before using.

What restrictions on field work will there be? Worker protection standards prohibit workers from entering treated areas for a period of time after treatment. The length of time depends on the chemical used and is given on the label. Restricted entry periods generally range from 4 to 48 hours.

Do tobacco buyers have concerns about insecticide residues? The number of materials that buyers have residue concerns about is increasing. Because of such concerns for certain materials, such as carbaryl (Sevin), we no longer suggest using them in tobacco. Communicate with your intended buyer to ensure that you are using only acceptable materials. Also, take care to prevent drift of any unregistered pesticides onto tobacco when they are being applied to an adjacent crop.

Will use of the insecticide restrict time of harvest? Regulations require a waiting period between application of insecticides and harvest. The length of time varies with the insecticide and is given on the label. For example, the pyrethriod lambda-cyhalothrin (Warrior) has a 40-day preharvest interval restriction, and bifenthrin (Brigade 2EC, etc.) cannot be applied after layby.

What effect will various insecticides have on beneficial insects? Some insecticides are more detrimental to beneficial insects than others. The *Bacillus thuringiensis* products (DiPel, etc.) do minimal harm to predators and parasites of tobacco pests. Fulfill is very specific to aphids and should have very little effect on beneficial insects. Tests in cotton indicate that spinosad (Blackhawk, Tracer) is somewhat detrimental to beneficials, but few data are available in

tobacco. Ongoing research on imidacloprid indicates that foliar applications may affect wasp parasitoids of caterpillars.

Is rotation between chemical classes an option? The answer to this is almost always yes. To prevent the buildup of insecticide resistance and minimize residues, it is best to avoid using the same insecticide over and over. Codes assigned by the Insecticide Resistance Action Committee (IRAC) allow growers to determine which insecticides have different modes of action and therefore can be used for rotation. See chapter 11 for an explanation of IRAC codes.

How much does the material cost? Cost is an important consideration, but remember, though, that the monetary cost of the insecticide is not the only cost associated with insecticide use. An inexpensive but poorly chosen insecticide can actually increase pest problems and production costs. Other long-term costs, such as environmental damage and human health risks, should also be considered.

Impact of Budworms on Tobacco

Budworms (actually a complex of tobacco budworms and corn earworms) are among our most difficult insect pests to control because they spend much of their time in the tightly rolled leaves of the bud. On the other hand, because tobacco can compensate for budworm damage, budworms may cause less loss than many growers may expect. Tests on North Carolina flue-cured tobacco in 1998 and 1999 examined the effect of budworm infestation on yield. Infestation levels of 40 percent (1998) and 100 percent (1999) did not significantly reduce yields compared to tobacco kept budworm free. Tests in 2002 and 2003 looked at the impact of budworm feeding on a plant-by-plant basis. In only one of six trials did a 100 percent budworm infestation significantly reduce yield, and then only when the infestation occurred early and there was an unusually high incidence of topping. It is clear that the treatment threshold (10 percent of plants budworm-infested) is a very conservative and safe threshold. Do not rush into making a treatment.

If insecticides are used, apply them carefully. Budworms are often hidden in the bud; as a result, sprays are sometimes not very effective. It is very important to treat when the bud is most open (usually in the early morning or at night). Direct the spray into the bud and onto the upper one-third of the plant, and use a high volume (25 to 50 gallons per acre). The spray nozzles should be as low over the bud as practical, no more than 12 inches above the bud (or about six inches above the uppermost leaf tips). Do not treat after topping except in very unusual cases.

Thrips and Tomato Spotted Wilt Virus

TSWV is moved from plant to plant by tiny insects called thrips. Tobacco thrips, the main vector in tobacco, are usually brown or black as adults and have delicate fringed wings that look a bit like an individual feather. Thrips are thin, much longer than broad, but are not more than an eighth of an inch long. Young thrips are smaller, wingless, and usually yellow. If you want to check for the presence of thrips, use a hand lens or other magnifying device. Alternatively, you may slap a leaf or flower head against a white surface and observe the dislodged insects.

Thrips usually spend the winter as adults or as pupae in the soil. Adults may hibernate in sheltered areas, but in mild winters (or at least during mild periods) they may be active on host plants, such as winter weeds. In the spring, thrips begin to move more actively and can spread to other hosts, including tobacco. Most of this movement is over distances that may reach several hundred yards, but thrips can sometimes be carried hundreds of miles by the wind. Generations are short, about two weeks when the weather is warm, and there may be several generations during the growing season.

Not every thrips you see on your tobacco is spreading TSWV. (Yes, the word thrips is both singular and plural.) Although many species of thrips exist, most of them either cannot carry TSWV or do not feed on tobacco. Moreover, even thrips that are able to carry the disease may not have picked up the virus from a diseased plant. Two species that do carry the virus and do feed on tobacco are the tobacco thrips (*Frankliniella fusca*) and the western flower thrips (*Frankliniella occidentalis*). In most years, the tobacco thrips is the most important vector of TSWV in the early season.

TSWV is carried from plant to plant inside the insect vector and not just on the outside of the insect's mouthparts. Thus, there is a delay between acquisition of the virus from one plant and transmission to another plant. The virus must be picked up by a very young thrips within a day or two of its hatching when feeding on a *non-tobacco* host. The same thrips cannot move the disease to another plant until the thrips matures into an adult.

Pesticides. Thrips are able to transmit TSWV very quickly, and almost all of these virus-carrying thrips come from outside the tobacco field. Foliar insecticides do not kill these thrips quickly enough to stop the spread of the virus. This type of spraying has not been successful in reducing disease incidence. Imidacloprid (Admire Pro and others) is effective at reducing TSWV transmission by altering thrips' feeding behavior. The application of Actigard, alone or in combination with Admire or Platinum, as a foliar spray (drench) to seedlings in the greenhouse may also reduce TSWV in certain years. (See chapter 8, "Managing Diseases," for details.) In addition to greenhouse treatments, Actigard can also be applied as a foliar treatment in the field. A thrips flight model developed by NC State University (linked through the Tobacco Portal, tobacco.ces.ncsu.edu) is effective for use in timing foliar Actigard applications to reduce TSWV incidence.

Cultural practices. Field selection and the transplanting date affect disease, but the transplanting date's effect is not consistent enough from year to year to include in a management plan. TSWV is most severe in early planted fields in most years, but in some years late-planted tobacco is most affected. Thrips flight timing is weather dependent.

Weed management. A few management considerations are important for TSWV control:

- Weedy small-grain fields and fallow fields destined for no-till soybeans or cotton may be important sources of virus-carrying thrips. Be careful not to disrupt these fields (for

example, do not use a broad-spectrum herbicide) just before or during transplantation of tobacco. Thrips will be forced from the dying weeds into a very susceptible tobacco crop. Weeds in these fields should be dead for at least two weeks before transplanting.

- Movement of the virus from summer annuals back to winter annuals is an important step in the virus cycle. If summer annuals can be killed before the winter annuals emerge, the cycle might be disrupted. This is another argument for a vigorous, early stalk-and-root destruction program in tobacco (including cultivation) and for good general weed control in late summer and early fall. Pay particular attention to fields with substantial carpetweed populations because this plant generates large numbers of thrips and is a reservoir for the virus.
- Whenever possible, manage your field borders to favor grassy vegetation over broad-leaf weeds. Grasses don't generate vector species of thrips and are poor hosts for the virus.

Organic Insect Management

We have many tools available for insect management in organic systems, but the "toolbox" is more limited than in conventional tobacco production. Some of the insecticides available are staples from conventional production that are also organically acceptable (e.g., *Bt* for budworm and hornworm control). Others are materials not previously used in tobacco. We have limited data about the efficacy of some of these materials in tobacco, but a few have been tested in small plot trials and in-lab bioassays (Table 9-8). We do know that many of these organically approved materials may be less effective or have shorter residuals than many synthetic materials commonly used for tobacco insect control. As such, following good agronomic practices such as timely topping, frequent monitoring to catch insect infestations early, and sometimes more frequent spraying are needed to keep insects below economically damaging levels in organic systems. A complete list of organically acceptable materials for insect control in tobacco is in the *2020 North Carolina Agricultural Chemicals Manual*.

Some organic growers plant rows of sunflowers or sunflower/buckwheat mixtures around the field edges or through the field in the "truck rows" to attract beneficial insects that feed upon aphids. Research conducted in our laboratory indicated that planting these flowers does not seem to attract caterpillar pests into the field but only reduces pest insect numbers over short distances (no more than 8 rows into a field).

Table 9-6. The efficacy of organically approved materials on key pests of flue-cured tobacco in North Carolina

Product	Rate	Aphids	Budworms	Flea beetle	Hornworms
Aza-Direct	2 pt/acre	Low	Low	Low/Moderate	NR
Dipel DF	1 lb/acre	NR	Moderate	NR	High
Dipel 10G Bait	10 lb/acre (0.03 oz/plant)	NR	High[a]	NR	Low[b]
EcoTec +TriTek	4 pt/acre + 1.5%	Low	Low	Low/Moderate	NR
GOS Neem 7-Way + Spray Clean	5% + 3 fl oz/pt neem	Low	Low	Low/Moderate	NR
Pyganic 1.4EC	64 fl oz/acre[c]	Low	Low	High	Low

[a] Bait must be applied directly to bud of plant.
[b] Result from experiment in Virgina similar results expected in NC.
[c] The label rate range for Pyganic EC 1.4 is 16 to 64 fluid ounces, and we do not currently have information to narrow this range.

PROTECTING STORED TOBACCO

Stored tobacco is subject to two insect pests: the cigarette beetle and the tobacco moth. Both of these pests are more active during warm weather, but they live through our winters in protected areas. Damage caused by the cigarette beetle resembles the small holes chewed by flea beetles in green tobacco. Cigarette beetles leave behind a powdery waste that can give tobacco an unpleasant flavor. Damage by tobacco moths ranges from irregular holes about the size of a quarter to leaves completely stripped except for major veins. Damage by moths may also reduce the grade of tobacco to NOG due to silk webbing, droppings, and insect skins and bodies in the tobacco.

Controlling an established insect infestation is difficult at best. The best strategy is to prevent it through good sanitation and vigilance. If the tobacco to be stored is from the final harvest, it is best to leave it in the barn because the barn will have been heat-sterilized and may be reasonably tight. Also, if an infestation occurs, the barn can be heated to kill the pests. The tobacco should be first dried at a low heat before the temperature is raised above 100°F. A temperature of 140°F maintained for two hours is sufficient to destroy any pests and has the added advantage of lowering the moisture content of the tobacco. A possible disadvantage to leaving the tobacco hanging is that it will likely come in and out of order with changing weather conditions. This tends to darken the tobacco over time.

If the tobacco is removed from the bulk barn for storage, be sure to thoroughly clean the storage area first. Move discarded tobacco and other organic refuse well away from the pack house and burn it. Tobacco and storage areas can be treated with *Bacillus thuringiensis* to help prevent tobacco moth infestation. Apply a fine spray to loose tobacco as it is being sheeted or baled. Rates for treatment with DiPel or Biobit are as follows:

- Tobacco: 2½ teaspoons DiPel DF or Biobit HP per quart of water per one hundred pounds of tobacco.
- Storage area: 6 teaspoons DiPel DF or Biobit HP per 2½ gallons of water. Use half a gallon per one thousand square feet of surface area.

Check stored tobacco periodically for signs of insects and new damage. Both insect pests are active primarily from April through October. Pests may also be active during warm spells in the winter, and tobacco should be checked then as well.

If tobacco moths are found, the tobacco should be treated with *Bacillus thuringiensis* as described above. Simply treating the outside of the bundles or bales may help but probably will not control an established infestation. Sheets should be opened and the tobacco treated as loose leaves as much as possible. If cigarette beetles are found, the only effective option is fumigation. Fumigation should be done by a professional because fumigants are very hazardous and must be carefully handled to be effective. Furthermore, regulations make it difficult for farmers to legally fumigate on their own. Fumigation controls both the cigarette beetle and the tobacco moth, but remember that it controls only those insects that are present in the fumigated area; it is not a preventive measure. Reinfestation can soon occur. Thus, sanitation in and around the storage area is essential.

Cigarette beetle and tobacco moth damage can greatly reduce the grade and desirability of tobacco. Thus, it is probably cost-effective (at least for loose or sheeted tobacco) to carefully sort out and discard damaged tobacco and other signs of damage before offering the tobacco for sale. If there has been a cigarette beetle infestation, even undamaged portions of a bundle should be shaken to remove any of the residues that impart off-flavors.

A PRECAUTIONARY STATEMENT ON PESTICIDES

Pesticides must be used carefully to protect against human injury and harm to the environment. Diagnose your pest problem, and select the proper pesticide if one is needed. The information presented here is not a substitute for pesticide label information. Follow label use directions, and obey all federal, state, and local pesticide laws and regulations.

Table 9-7. Conventional insecticides for remedial insect management in the field. Organically acceptable materials for insect control are listed in Table 9-6. Rates are for foliar applications only. See the* North Carolina Agricultural Chemicals Manual *for a comprehensive list of materials and application information. In general, information is provided for the most commonly used formulations of active ingredients available in multiple formulations. Carefully check and follow the label of the product you use. The label is the law!

Insect	Insecticide and Formulation	Rate per Acre	Reentry Interval (hrs)	Remarks
Aphids	Acephate (Acephate 97UP)	¾ lb	24	Good coverage is essential with any product.
	Acephate, IRAC 1B (Orthene) 97 PE	0.5 lb	24	
	Acetamiprid (Assail 30SG)	1.5–4 oz	12	
	Imidacloprid (Admire Pro)	0.7–1.4 fl oz (field foliar)	12	
	Lambda-cyhalothrin (Warrior) (Karate Xeon)	2.5–3 oz 0.96–1.92 fl oz	24	Note long preharvest interval.
	Pymetrozine (Fulfill 50WG)	2¾ oz	12	
	Thiamethoxam (Actara 25WDG)	2 oz	12	

Table 9-7. *(continued)*

Insect	Insecticide and Formulation	Rate per Acre	Reentry Interval (hrs)	Remarks
Budworms	Acephate (Acephate 97UP)	¾ lb	24	
	Acetamiprid (Assail 30SG)	1.5–4 oz	12	
	Bacillus thuringiensis			Many *Bt* formulations are also organically acceptable.
	(Agree)	2 lb	4	
	(Biobit HP)	1 lb	4	
	(Crymax)	1–1½ lb	4	
	(Deliver)	1–1½ lb	4	
	(DiPel DF)	½–1 lb	4	
	(DiPel ES)	2 pt	4	
	(Javelin WG)	1–1¼ lb	4	
	(Lepinox WDG)	1–2 lb	12	
	Chlorantroniliprole (rynaxypyr) (Coragen)	3.5–5 fl oz	4	
	Emamectin benzoate (Denim)	8 oz	12	
	Spinosad (Blackhawk)	1.6 oz	4	Use one or three solid cone nozzles no more than 12 inches above the bud. Apply 25–50 gal water/acre with at least 40–60 lb pressure.
Cutworms	Acephate (Acephate 97UP)	¾ lb	24	In late afternoon, apply in 25–50 gal water.
	Chlorantroniliprole (rynaxypyr) (Coragen)	3.5–5 fl oz	4	
	Lambda-cyhalothrin		24	Note long preharvest interval.
	(Warrior)	2.5–3 oz		
	(Karate Xeon)	0.96–1.92 fl oz		

Table 9-7. *(continued)*

Insect	Insecticide and Formulation	Rate per Acre	Reentry Interval (hrs)	Remarks
Flea beetles	Acephate (Acephate 97UP)	½ lb	24	For best control with any product, spray entire plant.
	Acetamiprid (Assail 30SG)	1.5–4 oz	12	
	Imidacloprid (Admire Pro)	0.7–1.4 fl oz (field foliar)	12	
	Thiamethoxam (Actara 25WDG)	2–3 oz	12	
Grasshoppers	Acephate (Acephate 97UP)	½ lb	24	
Hornworms	Acephate (Acephate 97UP)	½ lb	24	If applications are necessary during harvest, make them immediately after priming rather than before.
	Bacillus thuringiensis (Agree) (Biobit HP) (Crymax) (Deliver) (DiPel DF) (DiPel ES) (Javelin WG) (Lepinox WDG)	1–2 lb ¼–½ lb ½–1 lb ½–1 lb ¼–½ lb ½–1 pt 1/8–¼ lb 1 lb	4 4 4 4 4 4 4 12	Many *Bt* formulations are also organically acceptable.
	Chlorantroniliprole (Coragen)	5 fl oz	4	
	Emamectin benzoate (Denim)	8 oz	12	
	Spinosad (Blackhawk)	1.6 oz	4	

Table 9-7. *(continued)*

Insect	Insecticide and Formulation	Rate per Acre	Reentry Interval (hrs)	Remarks
Japanese beetles	Acephate (Acephate 97UP)	½ lb	24	
	Lambda-cyhalothrin (Warrior) (Karate Xeon)	2.5–3 oz 0.96–1.92 fl oz	24	Do not use Warrior within 40 days of harvest.
	Thiamethoxam (Actara 25WDG)	2–3 oz	12	
Slugs	Iron phosphate (Sluggo)	0.54–1 lb	0	Do not put bait on plants. Organically acceptable.
	Metaldehyde (Deadline Bullets)	12–40 lb	12	Apply at dusk. Do not put bait on plants.
Splitworms	Chlorantroniliprole (rynaxypyr) (Coragen)	3.5–5 fl oz	4	
Stink bugs	Bifenthrin (Capture LFR)	3.4–6.8 fl oz	12	Do not apply after layby.
	Bifenthrin + imidacloprid (Brigadier 2SC)	6.4 fl oz	12	Do not apply after layby.
	Lambda-cyhalothrin (Warrior 1CS) (Karate Xeon)	2.5–3 oz 0.96–1.92 fl oz	24	Do not use Warrior within 40 days of harvest.

10. CURING AND MECHANIZATION

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Energy efficiency is an integral part of sustainable agriculture. With the continued uncertainty in future energy costs, it remains important that growers apply all the recommended strategies to decrease energy usage and minimize production costs associated with curing. The best way to reduce energy costs is by improving and maintaining the energy efficiency of your existing curing infrastructure. Principally the heat exchanger retrofit systems require annual maintenance and adjustments to ensure they are operating correctly and efficiently. The information provided in this chapter can help you make the most efficient use of fuel and electricity while maintaining the highest cured leaf quality. Additional information on ordering, tray steam sanitation, standby power requirements, and machinery safety are discussed.

UNIFORM LOADING

Green leaf loading systems can improve handling efficiency, but more importantly they incorporate a weighing system to ensure that boxes are loaded with the same quantity of tobacco. Overloaded boxes can result in scalded tobacco, particularly on lower-stalk tobacco. More often, however, improperly cured tobacco results from uneven loading, which allows air to pass through less densely loaded areas while bypassing more densely loaded areas. Uneven drying results in longer curing times, thus increasing the electricity and fuel consumed. The bulk density—the pounds of green leaf per unit volume—significantly affects the airflow through the packed bed of tobacco. As the bulk density increases, the resistance the fan must overcome to produce a desired airflow also increases. Thus, an accurate green weight measurement will assist with determining the optimum loading rates for your particular barns and maximizing throughput.

Many growers increase the quantity of tobacco loaded per box as harvesting advances from the lower-stalk leaves to the upper-stalk leaves. Typical loading varies from 1,800 to 2,000 pounds for lower-stalk leaves; 2,000 to 2,200 pounds for mid-stalk leaves; and 2,200 to 2,400 pounds for upper-stalk leaves. Depending on the green leaf quality and barn airflow capacity, some growers may load more than 2,400 pounds per box with upper-stalk leaves. The loading rates discussed are typical for Long, Powell, or Taylor size boxes. DeCloet boxes have less volume and as a result are loaded with less green leaf for a given stalk position. Typical loading for a DeCloet box ranges 1,200 to 1,600 pounds from lower-stalk to upper-stalk leaves. Although the quantity of green leaf loaded varies with the box volume for a given stalk position, the resulting

bulk density will be similar. Regardless of the box volume, typical bulk densities vary from approximately 9 pounds to 13 pounds per cubic foot as harvesting advances from the lower- to upper-stalk leaves. The barn airflow capacity and quality of the harvested tobacco are important factors that affect the quantity of tobacco loaded per box for any stalk position. As a result, the loading rate for any size box may vary each growing season and between growers with similar make barns and boxes.

PRACTICE GOOD CURING MANAGEMENT

Proper control of temperature and relative humidity is essential for efficient tobacco curing. Typically, the relative humidity is measured indirectly by measuring both the dry- and wet-bulb temperatures. However, many growers have implemented automatic ventilation control systems that use a relative humidity sensor (dry sensor) instead of a wet-bulb thermometer. Although relative humidity is measured directly with this sensor, the wet- and dry-bulb temperatures are both displayed by the ventilation control systems because most growers still use dry- and wet-bulb temperature profiles to cure tobacco. A benefit of the dry sensor is the elimination of the routine maintenance required when using a wet-bulb thermometer. If you have concerns about the relative humidity sensor accuracy, compare the wet-bulb temperature displayed with a wet-bulb thermometer positioned in the barn. Additionally, ask the ventilation system or barn manufacturer about any calibration requirements. At a minimum, it is recommended to periodically compare the wet-bulb temperature displayed on the automatic system with an actual wet-bulb thermometer temperature measured in the barn during curing.

Dry-Bulb Temperature, Wet-Bulb Temperature, and Relative Humidity

The dry-bulb temperature, which is the actual air temperature, is measured with a conventional thermometer and is controlled by the thermostat. A wet-bulb thermometer is simply a dry-bulb thermometer that has its bulb wrapped in a cloth wick that is kept saturated with water.

As a result of the evaporative cooling process, the wet-bulb temperature will be lower than the dry-bulb temperature. The amount of cooling depends on the relative humidity. The relative humidity is a ratio: the actual weight of the water vapor in the air relative to the maximum weight of water vapor the air can hold for a given dry-bulb temperature. The higher the relative humidity, the slower the evaporation rate, and vice versa. The difference between the dry-bulb and wet-bulb temperatures determines the relative humidity of the air. As the difference between the dry-bulb and wet-bulb temperatures increases, the relative humidity decreases, and a smaller difference indicates an increase in the relative humidity. If the air were completely saturated, which would mean the relative humidity was 100 percent, the dry-bulb and wet-bulb temperatures would be equal. Table 10-1 shows the relative humidity (%) for varying dry-bulb and wet-bulb temperatures. The relative humidity is read at the intersection of a given wet-bulb temperature row and dry-bulb temperature column. For example, given a dry-bulb temperature of 144°F and a wet-bulb temperature of 112°F, the relative humidity is 37 percent.

Table 10-1. Relative humidity (%) for given dry-bulb and wet-bulb temperatures

Dry-Bulb Temperature (°F)

Wet-Bulb Temperature (°F)	92	94	96	98	100	102	104	106	108	110	114	118	120	124	128	130	134	138	140	144	148	150	154	158	160	164	168	170
80	60	55	50	46	42	36	33	30	28	25																		
82	66	60	55	51	47	43	39	36	33	31																		
84	72	66	61	56	52	48	44	40	37	34	29																	
86	78	72	67	62	57	52	48	45	41	38	32																	
88	85	79	73	67	62	58	53	49	45	42	36	31																
90	92	86	79	73	68	63	58	54	50	46	40	34	32															
92	100	93	86	80	74	68	63	59	55	51	44	38	35															
94		100	93	86	80	74	69	64	59	55	48	41	38	33														
96			100	93	86	80	75	69	64	60	52	45	42	36	32	30	26	22	21	18	16	15	13	11	10	9	8	7
98				100	93	86	80	75	70	65	56	49	46	40	35	32	28	25	23	20	18	16	14	13	12	10	9	8
100					100	93	87	81	75	70	61	53	50	43	38	35	31	27	25	22	19	18	16	14	13	12	10	9
102						100	93	87	81	76	66	58	54	47	41	38	34	30	28	24	21	20	18	16	15	13	11	11
104							100	93	87	81	71	62	58	51	45	42	37	32	30	27	23	22	19	17	16	14	13	12
106								100	93	87	76	67	63	55	48	45	40	35	33	29	26	24	21	19	18	16	14	13
108									100	94	82	72	67	59	52	49	43	38	36	31	28	26	23	21	19	17	15	14
110										100	88	77	72	63	56	52	46	41	38	34	30	28	25	22	21	19	17	16
112											94	82	77	68	60	56	50	44	41	37	33	31	27	24	23	20	18	17
114											100	88	83	73	64	60	53	47	45	40	35	33	30	26	25	22	20	19
116												94	88	78	69	65	57	51	48	42	38	36	32	28	27	24	21	20
118												100	94	83	73	69	61	54	51	46	41	38	34	31	29	26	23	22
120													100	88	78	74	65	58	55	49	43	41	37	33	31	28	25	24
122														94	83	78	70	62	58	52	47	44	39	35	33	30	27	25

Curing Phases

Typically the curing schedule is divided into three phases defined as yellowing, leaf drying, and stem drying. The actual curing schedule used will deviate due to factors such as tobacco ripeness and maturity, weather conditions during the growing and harvest seasons, airflow, and other influences. Tobacco harvested from different fields on the same farm may cure differently when exposed to the same curing environment. Use a temperature schedule based on your curing experience and the tobacco's response to the curing environment.

Yellowing involves a delicate balance between maintaining a high relative humidity and removing as much moisture as possible without excessive drying. The goal is twofold: to allow completion of the biological and physiological processes occurring in the leaf and to avoid overdrying or setting the color green. Removal of as much water as possible during yellowing while maintaining the proper humidity can reduce fuel consumption, thus improving energy efficiency. Likewise, as sufficient moisture is removed during yellowing, drying will help to improve airflow through the tobacco.

As curing progresses, the difference between the dry-bulb and wet-bulb temperatures increases, and the relative humidity decreases. When air is heated without changing the moisture content, both the dry-bulb and wet-bulb temperatures will increase. The dry-bulb temperature will increase more than the wet-bulb temperature, thus decreasing the relative humidity. The maximum dry-bulb temperature advance rate recommended is 2°F per hour during leaf drying and no more than 3°F per hour during stem drying. This gradual increase allows sufficient time for the moisture removal to keep up with the temperature increase, therefore minimizing the possibility of leaf scalding.

As long as the leaf retains sufficient moisture, the wet-bulb temperature and leaf temperature are approximately the same. If the leaf temperature exceeds approximately 113°F, the cells die, which produces browning or scalding. This is a result of too high a wet-bulb temperature and a slow drying rate. Therefore, after yellowing, the wet-bulb temperature should never exceed 105°F until the leaf lamina is completely dry. Once the leaf is dry enough to advance the dry-bulb temperature above 135°F, maintaining a wet-bulb temperature of 110°F will reduce fuel consumption. Many growers rely on experience to manage ventilation, but accurate control and minimizing fuel consumption requires monitoring the relative humidity.

Even growers with a lot of curing experience can have curing-related issues when there are extreme fluctuations in the weather conditions, typically over a short period of time, during the season that significantly stresses the plant. This has been the case for many locations in recent years. As a result, many questions are generated on how to change the curing schedule to maximize leaf quality. This is complicated even more when your tobacco contracting entity wants a particular cured leaf style or color. Unfortunately, there is not a simple answer. Detailed curing guidelines from a late-'70s Powell Manufacturing bulk barn operating manual are posted on the Tobacco Growers Information Portal. The portal includes discussions of typical dry- and wet-bulb temperature schedules, suggested adjustments for both that are potentially required for multiple

kinds of tobacco (lower-stalk, normal, over-ripe, heavily fertilized), and various conditions encountered during curing. A general guide is to slow down the processes of yellowing and leaf drying for tobacco that is grown under stress conditions.

Controlling the Wet-Bulb Temperature (Relative Humidity)—Ventilation

One of the most cost effective energy-saving strategies is the proper use of a wet-bulb thermometer. Measuring the wet-bulb temperature also allows the grower to monitor the actual leaf temperature during early phases of the curing process and will help to avoid the curing problems mentioned previously in this chapter. Opening the damper increases the fresh air intake or ventilation rate, which decreases the wet-bulb temperature and relative humidity. Closing the damper decreases the ventilation rate and increases the wet-bulb temperature and relative humidity, especially during early phases of the curing process. Typically, the ambient air relative humidity is lower than the relative humidity of the air inside the barn, especially during yellowing and early leaf drying. As curing extends into the latter phases of leaf drying and into stem drying, the relative humidity inside the barn can be much lower than the ambient air relative humidity. The ambient air relative humidity will also change from day-to-night with higher values occurring at night as the air dry-bulb temperature decreases. The ambient relative humidity can also increase significantly during rainy weather or other conditions and the ventilation rate might need adjusting to compensate.

Growers who do not measure or monitor the wet-bulb temperature are almost certain to overventilate to avoid browning or scalding the tobacco. Curing with a wet-bulb temperature that is lower than recommended will increase the quantity of wasted heat. Additionally, overventilation during yellowing may result in accelerated drying, setting the color green, especially the tobacco near the bottom of the boxes that are in contact with the air first. As the intake damper is opened more, the ventilation rate and fuel consumption increase. Additionally, less air is recirculated inside the barn, and more air is exhausted out of the vents. The air that exits the top of the boxes will seldom be saturated (100 percent relative humidity), which means that some of the available heat energy in the air will be lost to the outside. Additionally, the dry-bulb temperature of the air above the boxes or racks will be less than the air below the tobacco due to evaporative cooling. Depending on the curing phase, the dry-bulb temperature difference between the top and bottom of the boxes can vary 5°F to 20°F.

Excessive air leaks in the barn may make it difficult to maintain the desired wet-bulb temperature. Leaks increase the infiltration of fresh air pulled in by the fan to compensate for the air exhausted. This wastes fuel and energy because the air is exhausted out of the barn before it passes through the tobacco.

Automatic damper control provides continuous monitoring of the wet-bulb temperature or relative humidity, resulting in more accurate ventilation control, which can decrease fuel consumption during curing. As discussed previously, ambient conditions can also change in a short period of time, and as a result, ventilation adjustments may be required more frequently to maintain the desired curing environment and improve fuel efficiency. The amount of fuel

savings associated with using any automatic damper control will depend on how well a grower is currently managing the ventilation process.

During the 2007 season, multiple on-farm locations were used to compare automatic ventilation and manual ventilation control. At each location gas meters were installed on two identical curing barns to measure fuel consumption during each cure. An automatic ventilation control was installed on one barn at each location, and ventilation was controlled manually at an adjacent barn. For most locations, manual ventilation control did not include using a wet-bulb thermometer. The fuel savings and economic benefits associated with improved ventilation are summarized in Table 10-2. The fuel savings reported is the difference between the two barns at the end of the curing season (minimum of six cures) expressed as a percentage and gallons of LP gas. Averaged across all locations, the fuel savings was approximately 13 percent. At a few locations the growers did use a wet-bulb thermometer to assist with manual ventilation; as a result, the fuel savings were marginal. Although the automatic ventilation controllers used a wet-bulb thermometer during this on-farm evaluation, most have eliminated the wet-bulb sensor and now measure relative humidity, but the control will still display the wet-bulb and dry-bulb temperatures.

Many of the automatic ventilation control systems also have an optional monitoring system feature that transmits the dry-bulb and wet-bulb temperatures to a centralized location. This allows the grower to observe the real-time curing conditions of each barn from an internet-connected device (PC, laptop, smartphone). The remote monitoring capability has a significant time management benefit. Additionally, alarm conditions can be established to notify the curing operator when problems occur during the curing process. Although automatic curing control systems can help improve curing management, the desired dry- and wet-bulb temperatures and when to change both remain inputs based on curing experience.

Table 10-2. Annual fuel savings comparing ventilation control during the 2007 season

	Location						
	1*	**2**	**3**	**4**	**5**	**6**	**7***
Fuel savings (%)	1.43	12.63	12.15	16.42	28.33	16.50	2.23
Fuel savings (gals)	43	349	400	456	947	366	36
Savings per barn[1]	$62	$506	$580	$661	$1,373	$531	$52

* Grower used a wet-bulb thermometer with manual control

[1] $1.45 per gallon LP gas

Wet-Bulb Thermometer Location

If a wet-bulb thermometer is used to cure tobacco, a few maintenance steps are required to ensure accurate measurements. Keeping the wet-bulb wick from becoming dry during curing is critical to proper ventilation control. Theoretically, the wet-bulb temperature should be the same below and above the tobacco. However, the closer the wet-bulb thermometer is located to the heating system output, the more likely it is that small differences in the wet-bulb temperature may be observed when comparing this location to others in the barn. To obtain the most accurate wet-bulb temperature, a few guidelines are suggested:

- Place the wet-bulb thermometer far enough away from the burner output to ensure adequate mixing of the air but in a location with sufficient air movement across the wick. Typically, the wet-bulb thermometer is positioned on the floor below the curing containers, near the front of the curing barn. This allows easy access and is in an environment with sufficient airflow.
- Monitor the wet-bulb thermometer reservoir, and maintain it with water to keep the wick wet at all times. Change or wash wicks frequently (after each cure) due to the decrease in water absorption that commonly occurs. Impurities in the water and the unforgiving curing environment contribute to the decreases in moisture absorption.
- In some cases the airflow around the wick may be excessive, and at higher temperatures the increased evaporation rate will result in inaccurate measurements. Placing a piece of thin-gauge sheet metal on the floor beneath the wick and reservoir to shield the airflow has minimized this problem for some growers.

MAKE SURE YOUR EQUIPMENT AND BARN ARE ENERGY-EFFICIENT AND WELL-MAINTAINED

It is important to follow any annual maintenance requirements recommended by the heat exchanger, burner, and barn manufacturers to ensure they are functioning at optimum levels. The burners should be annually inspected and adjusted by a qualified barn service technician at the beginning of the curing season. Also, all electronic curing controls and temperature sensors should be inspected and recalibrated if needed to ensure proper operation.

The U.S. Tobacco Good Agricultural Practices (GAP) Program currently requires all curing barn heat exchangers to be tested for combustion product leaks every three years. Barn testing can be conducted by independent third-party companies or individual growers who have attended an N.C. Cooperative Extension training. The optimum time to check your heat exchangers for leaks would be immediately after the curing season or early in the spring. This would allow sufficient time to correct any heat exchanger issues prior to the next curing season. Some of the existing heat exchangers in use today are approaching 20 years of service and the average life span of a heat exchanger is 15 to 25 years, depending on a number of factors. Keep in mind that replacing an existing heat exchanger with a new unit may take longer than anticipated due to the limited number of manufacturers currently making new heat exchangers for tobacco barns. A different make and model heat exchanger may be required and the installation time might increase significantly. Additional information about the recommended barn testing equipment and procedures can be obtained from your county Extension center or viewed on the Tobacco Growers Information Portal.

Burner Efficiency

The single greatest reason for burner inefficiency is too little or too much air. When too little air is present, the burner will produce partially unburned fuel or smoke. Smoke not only wastes fuel but can deposit soot inside the heat exchanger, where it acts as insulation that can reduce the heat exchanger's efficiency.

Although an approximately correct burner air-fuel ratio may be set by eye (a blue flame instead of an orange one), the proper air-fuel ratio can best be achieved with a combustion analyzer. Refer to the burner manual or manufacturer for additional information on recommended excess air values. The manual may list the fan shutter setting for a given burner firing rate (BTUs/hour), but a combustion test should always be performed to verify the excess air percentage. Most fuel dealers or barn service technicians have some type of combustion analyzer and the experience to assist with burner adjustments. A properly tuned burner can result in significant improvements in the heat exchanger performance and longevity.

Heat Exchanger Efficiency

The energy efficiency of the heat exchanger is the percentage of the total heat entering from the burner that is extracted (exchanged) for practical use inside the barn. For the heat to be exchanged from the burning flue gases, it must pass through the walls of the heat exchanger. Many factors influence the exchange capacity and hence the efficiency of the heat exchanger. These include the shape and size of the heat exchanger, structural material type and thickness, the rate of hot gases flowing inside the heat exchanger, and the rate of air flowing over the outside surfaces of the heat exchanger. Additionally, the burner firing rate (BTUs/hour) can greatly influence the efficiency of a particular heat exchanger.

Growers should have their barn service technician check the burner-firing rate on every barn prior to each curing season. Typical burner-firing rates range from 325,000 to 450,000 BTUs/hour, depending on the amount of green tobacco loaded, heat exchanger design, fan output, and other factors. The heating system will operate most efficiently when the burner is operating at the lowest capacity that will allow the barn to maintain the desired temperature. The most heat is required during leaf drying, when the barn temperature is typically between 130°F and 150°F. Adjust the heat output of the burner so that the burner is operating nearly continually during this time. At a minimum, you should know the burner-firing rate on all your barns to accurately evaluate the heating system performance.

An Energy-Efficient Barn

Most bulk barns are situated on a 4-inch-thick pad of concrete. Some are insulated, but most are not. Typical fuel savings from on-farm studies comparing insulated and non-insulated barn pads ranged 3 percent to 6 percent. Even fuel savings in this range can result in a simple payback of three years or less, depending on the price of fuel. It may be too late to do much about an uninsulated pad now, but if you are thinking of putting in a new barn or moving an old one, you should consider placing an inch of extruded polystyrene foam board under the concrete to minimize heat losses through the ground.

Even a well-constructed barn will develop cracks and gaps over time. The natural daily cycle of heating and cooling will loosen screws, nails, and staples that secure the roofing and siding. Doors are particularly noticeable sources of maintenance problems. Hinges work loose, and gaskets get hard and torn, causing them to need periodic replacement. It is also a good idea to reseal the barn perimeter around the concrete pad with a good grade of butyl caulking

compound. Additionally, there are self-adhesive foam rubber gasket materials available that can be attached to the barn perimeter prior to positioning on the pad. Contact your county Extension center for more information about this material.

CURING ENERGY EFFICIENCY

Curing energy efficiency is the system's energy efficiency (barn plus burner and heat exchanger) and bottom line that can be quantified in pounds of cured leaf (marketed leaf) per unit of fuel consumed. For example, if you take out 3,000 pounds of cured leaf and consumed 300 gallons of LP gas for a given cure, the curing efficiency would be 10 pounds of cured leaf per gallon of LP gas (3,000 divided by 300) for that barn. These numbers may vary considerably, even in the same barn over a curing season, because they are affected by the quantity and quality of the green leaf loaded, stalk position, ambient conditions, heat exchanger and barn efficiency, and curing management.

Table 10-3 shows the estimated cost per pound cured for varying curing efficiencies and fuel costs. The fuel cost is expressed as dollars per unit and can be used for natural gas, LP gas, and No. 2 diesel. The greater the system energy efficiency, the lower the curing cost. As an example, if two growers were paying $1.00 per gallon for LP gas but their curing efficiencies averaged over the season were 10 pounds/gallon and 13 pounds/gallon respectively, the difference is approximately $0.023 (0.100 minus 0.077) per pound cured. Multiplying this difference by the total pounds cured can run into thousands of dollars over a season. As the price of fuel increases, the cost savings will also increase for a given difference in efficiencies.

It should be noted that this curing cost is for the fuel usage only. The total energy cost will also include the electrical energy used, most of which is consumed by the fan's electric motor. The electrical energy cost will depend upon your electric service provider, but rates can range from $0.08 to $0.13 per kilowatt-hour (kWh).

Table 10-3. Estimated curing cost (fuel only) for varying barn energy efficiencies and fuel cost

Fuel Efficiency (lbs/gal)	Fuel Cost ($/unit)						
	0.80	1.00	1.20	1.40	1.60	1.80	2.00
	$ / lb Cured Leaf						
8	0.100	0.125	0.150	0.175	0.200	0.225	0.250
9	0.089	0.111	0.133	0.156	0.178	0.200	0.222
10	0.080	0.100	0.120	0.140	0.160	0.180	0.200
11	0.073	0.091	0.109	0.127	0.145	0.164	0.182
12	0.067	0.083	0.100	0.117	0.133	0.150	0.167
13	0.062	0.077	0.092	0.108	0.123	0.138	0.154
14	0.057	0.071	0.086	0.100	0.114	0.129	0.143
15	0.053	0.067	0.080	0.093	0.107	0.120	0.133
16	0.050	0.063	0.075	0.088	0.100	0.113	0.125
17	0.047	0.059	0.071	0.082	0.094	0.106	0.118
18	0.044	0.056	0.067	0.078	0.089	0.100	0.111

Energy Content of Fuels

Although most growers use LP gas, Table 10-4 shows the approximate higher heating value of the fuels used to cure tobacco. Natural gas is typically sold in therms, and one therm is approximately the energy equivalent of burning 100 cubic feet of gas. A therm of natural gas has approximately 10 percent more energy than a gallon of LP gas. The heating value of wood reported is for seasoned or dried wood, which has a wet-basis moisture content of approximately 15 percent. Green wood is approximately 50 percent water, and the heating value is approximately half the value of seasoned wood. As a result of the differences in energy density (energy per unit volume), a grower using natural gas or fuel oil may consume fewer units in the same size barn loaded with the same quantity of tobacco compared with a grower using LP gas.

Table 10-4. Approximate heating value of fuels used for curing

Fuel (units)	BTU/Unit
LP gas (gal)	91,500
#2 fuel oil (gal)	139,000
Natural gas (therm)	100,000
* Wood (lb)	7,000

* Seasoned wood

To obtain the highest curing efficiency and significantly reduce curing costs, all the energy-saving guidelines for bulk curing need to be applied. Typically, curing efficiencies will be less with lower-stalk leaf and will increase with middle- and upper-stalk leaf. It takes significantly more fuel per pound of cured leaf to cure lower-stalk leaf compared to upper-stalk leaf. This

is because lower-stalk tobacco has a higher moisture content than upper-stalk tobacco, and the quantity of green leaf loaded per box is typically less with lower-stalk tobacco, resulting in less cured weight. Although many growers can estimate their seasonal fuel consumption, cured weights, and resulting curing energy efficiency, installing a gas meter on a single barn can provide accurate fuel consumption information to assist with evaluating your heating system performance and curing management. Contact your local fuel supplier or barn service technician for more information on installing a gas meter.

Over the past several years, the cost of conventional fuels has fluctuated significantly. As fuel prices change, a common question is which fuel is the most economical to use? The answer depends on price, fuel energy density, heating equipment efficiency, availability, and other factors. Table 10-5 compares the equivalent fuel cost per unit sold for several fuels used to cure tobacco. Note that the table values for wood chips are expressed as cost per ton because this fuel is typically sold by weight. The costs determined are based on the heating values shown in Table 10-4, and the heating system efficiency is assumed to be the same for all fuels. Most heat exchanger burners when properly tuned operate at thermal efficiencies of 80 percent or higher. However, if not properly tuned they can operate at much lower values. Modern wood-fired boilers have heating system efficiencies of 80 percent or higher as a result of the control technologies implemented and equipment design. Table 10-5 is arranged so that for a given fuel type and price selected, the equivalent costs for the additional fuels will be in the same row. For example, if you are paying 50 cents per therm for natural gas, the equivalent cost for LP gas is 46 cents per gallon, 70 cents per gallon for fuel oil, and $70 per ton for wood chips. During the 2014 season, some growers were paying 70 cents per therm for natural gas and $1.10 or more per gallon for LP gas. The price of LP gas would need to decrease to 64 cents per gallon to be equivalent to 70 cents per therm for natural gas, assuming the heating system efficiencies are the same. Although LP gas prices have decreased significantly in recent seasons, the long term price outlook remains unclear. Table 10-5 can be used to compare fuel types and can be helpful in deciding which fuel is the most cost effective to use as prices for each type change. Keep in mind that any comparison of heating costs must also include the capital and labor costs, if applicable, in addition to the fuel cost. The actual heating system efficiency needs to be taken into account also, if different, when comparing fuel types.

Table 10-5. Fuel cost comparison

Natural Gas ($/therm)	LP Gas ($/gal)	No. 2 Fuel Oil ($/gal)	Wood Chips ($/ton)
0.20	0.18	0.28	28
0.30	0.27	0.42	42
0.40	0.37	0.56	56
0.50	0.46	0.70	70
0.60	0.55	0.83	84
0.70	0.64	0.97	98
0.80	0.73	1.11	112
0.90	0.82	1.25	126
1.00	0.92	1.39	140
1.10	1.01	1.53	154
1.20	1.10	1.67	168
1.30	1.19	1.81	182
1.40	1.28	1.95	196
1.50	1.37	2.09	210
1.60	1.46	2.22	224
1.70	1.56	2.36	238
1.80	1.65	2.50	252
1.90	1.74	2.64	266
2.00	1.83	2.78	280
2.10	1.92	2.92	294
2.20	2.01	3.06	308

Note: Heating system efficiency is assumed equal for each fuel type.

MOISTURE ADDITION IN CURED TOBACCO

Green tobacco is approximately 80 percent to 90 percent water. At the end of the curing cycle, the tobacco is essentially 0 percent water. At this stage, tobacco is much too brittle to handle without shattering. Therefore, moisture must be added back into the tobacco at the end of the cure to enable handling and market preparation. Too much moisture, however, can cause the tobacco to heat, darken, and decay and will ultimately ruin its desirable qualities.

Cured tobacco, like many organic materials, is hygroscopic. Hygroscopic materials have a physical (as opposed to a chemical) affinity for moisture. In the case of tobacco, this moisture is usually absorbed from the water vapor in the air surrounding the leaf. The absorption of water by cured tobacco leaves is a complex process that depends on many biological and physical factors. Biological factors include leaf properties that vary with variety, cultural practices, stalk position, and weather. The important physical factors include ordering temperature and humidity, air velocity around the surface of the leaf, and quantity and arrangement of the leaves.

It is well-known that the rate of moisture absorption (usually expressed as a percentage of moisture increase per hour) increases with increasing relative humidity. At higher relative humidity, more water is in the air and available for absorption by the tobacco. It is probably less well-known that moisture absorption rates also increase with increasing temperature. In addition, stalk position and leaf quality affect the rate of water absorption. Lower-stalk or thin, poor-quality tobacco has a faster absorption rate than thicker, upper-stalk, or better-quality tobacco.

Accurate Conditioning of Tobacco at the End of the Cure

The rapid and satisfactory ordering of flue-cured tobacco after curing is essential to both efficient use of barn space and leaf quality. Purchasing companies have established upper moisture limits that, if exceeded, will result in rejection of the baled tobacco, but some companies also have a price incentive for tobacco delivered within a specified moisture content range. The several methods or combinations of methods that are now used to add moisture back into the tobacco often result in wide variations in moisture content from barn to barn and even within the same barn.

Many growers use the existing water supply that operates at low pressure with a group of nozzles positioned in the barn. This is a slow and uneven method that often wets the tobacco in some places while increasing the moisture very little in others. Some growers rely exclusively on the moisture content in the ambient air, which can vary significantly as weather conditions change. Running the fan with the vents fully open brings moist outside air past all the tobacco in the barn but, depending on the weather, this process can vary significantly with time. To properly order tobacco, the addition of water at the end of the cure must follow certain guidelines, outlined below.

Research has demonstrated that the best time to start ordering is immediately after the end of curing, while the barn and tobacco are still warm. However, you should allow the heat exchanger time to cool down before adding water. Some growers may refrain from this practice because they mistakenly fear that moisture will darken the tobacco. Moisture will indeed darken warm tobacco, but only if the moisture is liquid water.

Decrease the water droplet size to increase the rate of water absorption into the leaf. The droplet size must be small enough to allow the water to evaporate before it encounters leaves of tobacco. Also, more water remains as vapor in the air circulated through the tobacco. This usually requires special nozzles and line pressure at 500 pounds per square inch (psi) or higher. Water introduced into the air in droplets too large to evaporate will stick to the first surface the droplets encounter (usually the floor or bottom leaves in the barn) and go no further. Some growers assume that the moisture will migrate and even out when these tobaccos are mixed when baling. Pockets of high-moisture tobacco inside a generally lower-moisture bale will heat and decay long before the moisture has had a chance to migrate. At the end of ordering, turn off the water, close the vents, and operate the fans for at least another hour to allow the moisture in the tobacco to even out and enter the midribs.

Most experienced growers have a good estimate of how much cured tobacco they can expect from their barns. If a grower knows the cured weight target moisture content, it is simple to determine

how much water to add. For example, if a grower expects to remove 2,600 pounds of tobacco from his barn at 15 percent moisture content, 2,600 multiplied by 0.15 equals 390 pounds of water.

Thus, 390 pounds of water must be added to the tobacco at the end of the cure. Because one gallon of water weighs approximately 8.34 pounds, 390 pounds of water equals approximately 47 gallons. If the pump can atomize 30 gallons of water per hour (so that essentially all the water enters the tobacco), then it should theoretically take approximately 1.6 hours (47 divided by 30) to bring the barn of tobacco into order. However, actual ordering systems are much less than 100 percent (< 50 percent) efficient and require additional time.

Some growers have constructed homemade ordering systems out of PVC or steel pipe with a group of nozzles. If the waterline pressure and the nozzle size are known it is easy to estimate the gallons per hour introduced into the barn. For example, a typical water supply pressure is 40 psi. Using four hollow-cone TX-2 nozzles at 40 psi will deliver approximately 0.132 gallons per minute or 7.92 gallons per hour (0.132 multiplied by 60). Nozzle capacity can be found in the manufacturer's catalog and is rated in gallons per minute (gpm) for a given pressure. To deliver 45 gallons of water into the airstream would thus require approximately 5.7 hours (45 divided by 7.92). Knowing the gallons required for a desired moisture content and the ordering system output capacity can assist growers with more consistent and accurate moisture addition. Table 10-6 lists the approximate gallons of water required for varying cured weights and moisture contents.

Table 10-6. Gallons of water required to bring flue-cured tobacco to a given moisture content

Cured Leaf Weight (lb)	Moisture Content of Tobacco (% Wet Basis)						
	12	13	14	15	16	17	18
2,000	29	31	34	36	38	41	43
2,200	32	34	37	40	42	45	47
2,400	35	37	40	43	46	49	52
2,600	37	41	44	47	50	53	56
2,800	40	44	47	50	54	57	60
3,000	43	47	50	54	58	61	65
3,200	46	50	54	58	61	65	69
3,400	49	53	57	61	65	69	73
3,600	52	56	60	65	69	73	78
3,800	55	59	64	68	73	77	82
4,000	58	62	67	72	77	82	86
4,200	60	65	71	76	81	86	91
4,400	63	69	74	79	84	90	95
4,600	66	72	77	83	88	94	99
4,800	69	75	81	86	92	98	104
5,000	72	78	84	90	96	102	108

Some commercially available portable ordering units increase the existing line pressure significantly to increase atomization of the water. These units increase the water supply pressure to 600 psi and higher, which results in decreasing the water droplet size and increasing leaf absorption efficiency. Some units have an electromechanical or digital timer to operate the pump continuously or intermittently. Intermittently operating the water pump allows more time for the fan to move the moisture upward through the tobacco and minimize excessive wetting of the tobacco in the bottom of the containers. A typical cycle operates the pump for one hour on and 30 minutes off, but the actual duty cycle can be customized.

On-farm tests conducted in past years comparing commercial high pressure units operated intermittently with existing systems at a given location resulted in reducing the quantity of water used and time required to complete the process. The ordering system output flow rate ranged 0.75 gpm to 1 gpm. Growers using the intermittent operation observed an improvement in moisture uniformity throughout the barn and consistency with the time required to complete the ordering process compared to their existing ordering method. However, some barns do not have a convenient location to insert the nozzle boom; in this case, growers might have to modify the unit boom configuration or the barn accessibility. Some growers use a high-pressure sprayer pump that will significantly increase water atomization, but the output flow rate may be significantly higher than 1 gpm, causing water to be added much faster than the leaf absorption rate. As a result, most of the water collects on the barn floor and saturates the area around the barn.

Any ordering system output can be measured using a procedure similar to calibrating spray equipment. Simply collect each nozzle output with a volumetric measuring cup for one minute of operation. To determine the ordering unit total volume output in gallons per minute, add the measurements for each nozzle and convert from ounces to gallons (128 ounces equals 1 gallon), if needed. Comparing the measured nozzle output with the flow rates listed in the manufacturers catalog for a new nozzle will also help identify those with significant wear problems that need replacing. Typically, as the nozzles wear, the flow rate will increase for a given operating pressure. Introducing water into the airstream at excessive rates will saturate the tobacco in the bottom of the containers first, which may cause quality problems. A targeted system output of approximately 1 gpm may improve any ordering system efficiency and uniformity. However, a higher gpm may be needed later in the season when dealing with upper-stalk tobacco and the ambient temperatures have decreased significantly. Increasing the system operating pressure to improve atomization will assist with increasing leaf absorption efficiency while avoiding excessive flow rates at any pressure. Additionally, implementing a timer for continuous or intermittent operation will assist with improving the ordering process control and management.

TRAY SANITATION USING STEAM

Growers have primarily used methyl bromide to eliminate pathogens from greenhouse float trays prior to re-seeding each year. However, methyl bromide is no longer available and the existing options to completely eliminate the inoculum of pathogens in used trays are to purchase new trays each season, which is cost prohibitive, or sanitize them with steam. Steaming trays has been available for many years, but the simplicity and cost effectiveness of chemical fumigation has limited widespread adoption of this method at the farm. There are a few individuals and businesses that steam trays for growers, but that can range in cost from $4 to $6 per acre. Multiple equipment manufacturers are making commercially available steam sanitation systems, but more growers are interested in information related to equipment specifications and costs to build their own steam sanitation system.

Based on past research, the recommendations are to steam trays at 176°F (80°C) for 30 minutes. However, recent work has shown it is possible to steam strays at a lower temperature for a longer period of time and still maintain 100 percent control. The results indicated that steaming trays at 158°F (70°C) for 2 hours can also be utilized. The benefit of a reduced temperature threshold is the reduced performance specifications required of the steam equipment used for this process. Growers with a limited capacity steam generator combined with an uninsulated tray storage structure and low ambient temperatures might not be able to obtain the 176°F threshold required for the 30 minute exposure time. Although the alternative temperature requirement is lower, the time is increased significantly, and the quantity of trays steamed per day will decrease. However, reduced system throughput may not be an issue for most growers. Although the reduced temperature and extended time was shown to work in a single study, the higher temperature recommendation has proven to be effective over a number of years and actual on-farm results. It should also be emphasized that steam must be used, not dry heat.

Simply placing the trays in a bulk barn, or other structure, and advancing the heat to the desired temperature at the corresponding time required will not be very effective. This method may also result in other undesired outcomes. Steam is more effective at penetrating cracks in the tray walls to ensure contact with all the potential pathogens. Proper protocol should be followed when handling the trays and placing them in storage to avoid re-contamination of the trays. Also be aware that Styrofoam trays will shrink if exposed to elevated temperatures (> 200°F) and the amount of damage will increase with exposure time. Any changes in tray dimensions would certainly result in problems during reseeding.

Many growers can build or purchase an insulated structure to store the trays for steam sanitation, but most will not have the steam generating equipment needed for this application. A typical hot-water pressure washer is not designed to produce the large volume of steam that is required to effectively sanitize trays. These units are primarily designed to produce a large volume (2-3 gpm) of hot water at high pressures. Although these units are capable of producing some steam, the typical output will contain a mixture of steam and mainly hot water. If trays are going to be steam sanitized prior to seeding during winter months, then the tray storage structure should be insulated due to the lower ambient temperatures. At least 1 inch of foam insulation is recommended to minimize heat loss and to decrease the time required to complete the process. Growers who are considering steaming trays after transplanting during the spring may not necessarily need as much insulation because ambient temperatures will be higher but, depending on ambient conditions, the process time could be extended without any insulation added to the structure. The thermal energy requirements (BTU/hr) will be based on the steam generator water supply flowrate, quantity of trays (size of structure), structure design, and ambient temperatures. Assuming all other variables are held constant, as the tray container volume increases, the thermal energy requirements also increase to complete the process in a practical amount of time. There are commercially available steam units, but if the structure volume (tray capacity) and steam capacity are not properly matched, the tray throughput can be significantly reduced. This will result in an increase in the time required and cost to sanitize a given acreage. Any structure should also incorporate a manifold to distribute the steam around the trays. Ideally, the manifold would be positioned beneath the trays in a lower air plenum that is approximately 2 to 4 inches high. This would be the distance measured from the floor to the bottom of the trays. A general guideline for the steam distribution system is to include ¼-inch or larger diameter holes spaced 12 inches to 18 inches apart on the manifold lines for the steam to exit, to minimize flow restrictions, and to improve distribution around all the trays. The steam unit outlet hose should have an inner diameter of 1 inch or larger to minimize flow restrictions and have a temperature and pressure rating greater than the output of the steam unit.

We recently constructed a steam sanitation system from commercially available components in order to collect on-farm performance information. The steam generator was an add-on heating unit from Northern Tool designed to convert an existing cold water pressure washer into a hot water/steam pressure washer. We added some additional diagnostic and safety components to improve adaptation to our application. The tray container was a 24-foot commercial shipping

container reduced to a length of 15 feet so the new volume would hold approximately 1,200 float trays. We reduced the container length to improve system mobility and to reduce the equipment needed to move a conventional size container. The container was also completely insulated with approximately 2-inch foam board. The steam system performance information collected from multiple locations is summarized in Table 10-7. At two locations the growers already had a structure to hold trays and only the steam generator we made was utilized to assist with the sanitation process. The float trays were steamed prior to reseeding their greenhouses at both of these locations. The remaining three locations used both the tray container and steam unit after they finished transplanting to sanitize their trays. This is noted in the varying dates (February to June) the steam system was used. The process turnaround time per cycle includes the time required to load and unload the trays and the time required to raise the container temperature to 176°F and maintain that temperature for 30 minutes. The number of trays loaded per cycle ranged from 400 to almost 1,500 trays, which would correspond with approximately 20 to 65 acres per load. This is simply an indication that the system can work for operations of various sizes. Details on how to build the steam generator based on the Northern Tool unit are available from your N.C. Cooperative Extension center.

Table 10-7. 2017 float tray steam sanitation system on-farm performance results

Location	Date	Number of Trays per Cycle	Process Turnaround (hr)
*Wilson	February 16	1,200	1.5
*Person	March 3	400	.5
Wayne	May 17	1,200	< 2
Johnston	May 26	1,450	2.5
Johnston	June 20	1,400 and 1,000	4

*Steam generator used only

Any structure purchased or constructed for steam trays should have at least one thermometer incorporated on the structure that can be easily seen to accurately monitor the process temperature. Additionally, a thermometer and pressure gauge should be incorporated in the steam supply line to monitor the steam parameters entering the structure. Although any thermometer mounted on the structure will display the temperature measured near the wall, the actual temperature distribution throughout the structure may not be uniform initially during the process. The temperature distribution will become more uniform over time. It should be noted that due to the multiple variables involved, the time to reach a uniform temperature will vary with steaming systems used. Another important reason to monitor the process temperature is to avoid exposing the Styrofoam trays to temperatures greater than 200°F for any amount of time during the process.

Safety Concerns

Steam can cause serious injuries, and correct safety precautions should be used with any equipment that produces steam. The main danger of working with steam is burns or scalding to

the skin. The tray sanitization application will result in exposure to steam temperatures equal to and exceeding 212°F. Wear appropriate personal protective equipment (PPE) such as gloves, eye protection, long pants, and boots. Remember the steam distribution system and related components will remain at elevated temperatures after the process has stopped during loading and unloading. Steam will reduce visibility, which could result in other accidents. Condensation of steam will cause floors to become slippery, which will increase the risk of slipping or falling. Steam can also get into electronic devices and outlets resulting in an electric shock. The system should be operated away from outlets, and be sure to cover any electrical equipment in close proximity during the process and ensure it is dry before using. Also, do not bypass or disconnect factory installed safety features incorporated on any commercial steam or hot-water equipment purchased or modified for this application.

SELECTING AND USING STANDBY ELECTRIC POWER EQUIPMENT

Electricity plays a critical role in agricultural operations, and the importance of a continuous electrical supply is not always recognized until a power outage occurs. Today, tobacco farm operations use standby power equipment or back-up generators to operate their bulk-curing barns during a widespread loss of power following a hurricane or tropical storm event. The loss of power can have a great effect or almost no effect at all on the quality of the tobacco in the barn, depending on the *stage of the cure and the length of the power outage.* Further, as is the case with any storm after it passes, the loss of power delays harvesting, which results in the potential loss of tobacco still in the field. Standby power equipment can eliminate some of the frustration, inconvenience, and economic risks of a power interruption. Farm operations must compare the cost of standby power equipment to the potential financial loss and inconvenience resulting from extended power outages.

The most critical period for damage to occur in the curing process is during late yellowing and early leaf drying (105°F to 125°F dry-bulb / 95°F to 105°F wet-bulb). During these stages, tobacco will tolerate less deviation from the recommended wet-bulb and dry-bulb temperatures than later in the cure. Tobacco leaves are alive when harvested and remain alive in the barn until near the end of yellowing. During this time the tobacco, like all living tissue, is respiring: using oxygen; burning sugars and starches; and giving off water vapor, carbon dioxide, and heat. Without the circulation of air to prevent the buildup of heat, the temperature of the tobacco can increase significantly in a short period of time, resulting in widespread damage. The damage might be minimized, especially early in the yellowing stage, if the tobacco can be cooled to near ambient conditions by opening all barn air vents and doors to allow heat to escape. If generator capacity is not available, tobacco that would be in this critical curing stage during an extended power outage might be better left unharvested.

Unlike yellowing, leaf drying and stem drying are primarily physical processes. During this time, biological activity ceases, little or no heat is produced, and the tobacco can tolerate a much longer interruption of power without apparent damage. The damage that is likely to occur will

be from the wicking of moisture back into the leaves from the still-moist stems. This condition, known as "run back" or "vein darkening," will occur more rapidly at early stem drying than later in the cure. Barns that are at dry-bulb temperatures (160°F to 165°F) within 18 to 24 hours of completion may be able to tolerate several days without power with little apparent damage. If generator capacity is limited, a grower could by-pass barns near the end of stem drying and use the equipment to provide power to barns in the more critical curing stages.

Standby power equipment can be generally classified as stationary or portable units. Stationary units use an internal combustion engine coupled to a generator. Large engine-driven units are commonly referred to as a "generating set," or a "genset" for short. Portable engine-driven units may be driven by a small engine fixed to the generator or by the power take-off (PTO) of a tractor. Stationary units are typically large (> 20kW) and may be automatically controlled. Those systems can automatically start and transfer the electrical loads to the standby unit in just a few minutes when the loss of power occurs. Portable, small engine-driven units are used for smaller electrical loads (<7.5 kW) and are generally not large enough to supply sufficient power to a single curing barn. PTO-driven units are the most common in agricultural applications because the input power is typically available from a tractor. Approximately 2.25 hp per kW of electrical power is required to properly run a generator, regardless of the generator type. For example, a 50 kW generator would require a tractor rated at least 113 hp (50 multiplied by 2.25). Tractor performance is typically rated at the PTO.

Generator (Alternator) Selection. Although commonly referred to as "generators," the devices used for standby electrical power service are actually "alternators." By definition, generators produce direct current (dc) while alternators produce alternating current (ac). Alternators are rated by their power output, measured either in watts or kilowatts (kW). Most alternators are rated in kilowatts (1 kilowatt = 1,000 watts). The standard rating is usually given on the alternator's nameplate but may not be its maximum output. Some alternators have substantial overload capacity, although this additional capacity is always limited to short periods of operation. When two ratings are provided on the unit nameplate (for example, 10,000/5,000), the larger number is the short-term overload rating and the smaller number is the continuous-run rating. When selecting an alternator, carefully consider *both* the run capacity and the overload capacity. Some large alternators may be rated in kilovolt-amperes (kVA) or volt-amperes (VA). Their approximate power output in kilowatts may be determined by multiplying the kVA rating by 0.8. It is important that the engine or tractor selected be capable of prolonged operation at high output. The engine should also be capable of maintaining a very constant speed over a wide range of load conditions. For this reason, either a mechanical or electronic speed control (governor) is normally required.

Almost all electrical power used on farms is either 120- or 240-volt, single-phase, 60 hertz (cycles per second), but many larger size operations now operate on three-phase power. If properly connected, three-phase alternators may be used to power single-phase equipment, but three-phase equipment ***cannot*** be operated with single-phase power without expensive phase conversion equipment. The alternator selected ***must*** be able to produce power at the same voltage and frequency required by the equipment. Most large alternators and many small ones

are equipped with frequency, voltage, and current meters. These are necessary to ensure the production of power at the correct specifications. The voltage should register at least 230 volts for a 120/240-volt service or 115 volts for a 120-volt service. Frequency should never be less than 57 hertz nor greater than 63 hertz. Deviations from these ranges can destroy the alternator and the electric motors.

Sizing the Alternator (Generator). The capacity of the alternator required depends primarily on two factors. The first factor is the size and nature of the load. Electrical loads are of two types: inductive and resistive. The prime example of an inductive load is an electric motor. Resistive loads typically convert current into heat, such as in incandescent lights and electrical heaters. With resistive loads the current rises immediately to the steady-state value without first rising to a higher value. They require the same power to start as to run. However, electric motors can require three to five times their rated full load current while starting. The larger starting loads of electric motors *must* be taken into consideration when calculating the total electrical load. The starting and full-load running power requirements for various size single-phase motors are tabulated (Table 10-8). A typical 10-box bulk curing barn uses a 10 hp electric motor to operate the fan, but 5 and 7.5 hp motors are also used on different size barns. If you are unsure, look at the electric motor nameplate to confirm the size or consult the barn manufacturer. The device consuming the most electricity in a bulk curing barn will be the fan electric motor.

The second factor to consider is whether all or only part of the equipment will be operated at the same time. Alternators and electric motors are designed to operate at a certain voltage and frequency. Even small deviations from these ratings for short periods because of overload will reduce service life. Large deviations (20 percent or more) can quickly cause severe heating of the windings and destroy the equipment. The total required alternator capacity may be substantially reduced if part of the load may be switched off temporarily. Situations where motors start automatically are particularly problematic because, sooner or later, several motors starting at the same time will place a huge overload on a system. Taking steps to prevent simultaneous starting of motors or load management can reduce the required capacity and prevent overload.

Table 10-8. Starting and full-load running power requirements for various size single-phase, 60 Hz electric motors

Motor Size hp (kW)	Approx. Amps @ 240 Volts	kW Required	
		Starting	Running
½ (0.37)	5	2.3	0.6
¾ (0.56)	7	3.4	0.9
1 (0.75)	8.0	4.0	1.0
2 (1.50)	12.0	8.0	2.0
3 (2.24)	17.0	12.0	3.0
5 (3.73)	28.0	18.0	4.5
7.5 (5.60)	40.0	28.0	7.5
10 (7.46)	50.0	36.0	9.0

Transfer Switch. The National Electrical Code (NEC), the power utilities, and good sense require that any standby generator be connected to the load through a transfer switch. This piece of equipment is essentially a double-throw switch that prevents the accidental connection of the alternator and the power company to the load at the same time. The switch is designed so that either the alternator or the power grid is connected to the equipment but never both. Unless a transfer switch is used, power could be fed back onto the power line from the alternator, endangering those working to repair the lines. In addition, the alternator would be destroyed if the power grid were reenergized while the alternator was connected to the load. The switch must be rated to carry the highest potential current. Common sizes are 100, 200, and 400 amps. The purchase of a genset with automatic transfer equipment is a major investment, and professional assistance in designing and selecting such units is recommended.

Wiring. The wiring of standby alternators, even when temporary, should always comply with the NEC (or any local code which may prevail) and be installed by a licensed electrician. Alternators should be well-grounded and positioned as close as practical to the loads to reduce the wiring length. Every effort should be made to protect these lines from mechanical damage. Wire should be run over-head if at all possible; where this is not possible, the lines should be buried. There is no wire designed to withstand being driven over repeatedly by tractors and other vehicles commonly used around farm operations.

Starting. Everyone that might be involved with operating a standby power unit should be completely familiar with its set-up and operating procedures. For manually operated standby systems, the following sequence of operations should be followed:

1. Call your power company and report the outage.
2. Turn off or disconnect all electrical equipment.
3. Assuming the alternator was previously wired into place through an approved transfer

switch, start and bring the generator up to operating speed. Check the frequency and voltage meters for correct readings.

4. Put the transfer switch into the standby power position.

5. Switch on the electric loads (motors) one by one. Start the largest electric motor first if different size motors are used. Add each motor only after the previous one has reached its full operating speed.

6. Check the frequency and voltage meters often to ensure they are still within limits. The minimum operation voltage for 240-volt service is 200 volts and for 120-volt service is 100 volts.

7. When regular power is restored, disconnect or switch off each load in turn. Then turn off the standby power unit.

8. Move the transfer switch back to its normal position. Reconnect or switch on each load.

Example questions and calculations:

What is the largest alternator capacity that may be powered by a tractor that produces 92 PTO horsepower?

92 / 2.25 = 41 kW

What size alternator is required to power 10 bulk barns, each with a 10 horsepower fan motor?

From Table 10-8, a 10-horsepower motor requires 9 kW to run, but requires 36 kW to start. Each motor is started in sequence, and then the last motor will be started while the first four are already running.

Then: 81 kW (9 times 9) + 36 kW = 117 kW required. The tractor PTO power needed is at least 264 hp (117 times 2.25).

What can be done if your alternator does not have sufficient capacity to operate all your barns?

It is possible to switch the power between barns manually often enough to prevent the tobacco from being ruined. Those barns at the early stages of the cure may require a nearly constant supply of power, but the barns with only 24 hours or less remaining in the curing process can be left unpowered for several days.

Maintenance

Proper, timely maintenance is imperative to ensure the standby power unit is in good running order so it will be ready for immediate use when needed. Always be familiar with and follow the maintenance and safety instructions in the manufacturer's manual. Standby generators should be operated periodically at least 50 percent of the rated load to be sure they are functioning

properly. Units should be kept clean at all times. Accumulation of dust and dirt may cause a unit to overheat when operating. Units should be stored out of the weather, but not covered with a tarp because the covering would allow moisture to condense inside and potentially cause rust.

SAFE FARM MACHINERY OPERATION

Modern agriculture has become increasingly mechanized to reduce labor and improve efficiency, but this has also increased exposure for both operators and bystanders to machinery hazards. Agriculture continues to rank as one of the most hazardous industries in the United States, and farmers are at a very high risk for fatal and nonfatal injuries. Additionally, farming is one of the few occupations in which family members and bystanders are also at risk. The fact that agricultural machinery uses tremendous power makes operation a potential hazard for both the operator and bystanders. For families and communities involved in a farming accident, the toll is huge. Even though manufacturers try to ensure that machinery is as safe as possible, the nature of the work creates inherent hazards that cannot be completely removed. Knowledge of some general safety procedures and learning specific safety information about each piece of machinery used could save lives and greatly reduce pain and expense.

Flue-cured tobacco production is mechanized extensively and, as a result, many machine hazards are present. Tobacco harvesters, balers, green and cured leaf handling systems, forklifts, and tractors results in specific machinery hazards during operation. Harvest season is a busy time for farm operations, and time means money when it comes to yields, production schedules, and operating costs. Unfortunately this is also a very dangerous season. Accidents can occur as a result of taking shortcuts to perform routine tasks, operator physical or mental condition, or failing to follow safety practices. The typical operating environment can have extreme temperatures, excessive noise and vibration, slippery conditions, etc. that are all accident factors. Accidents are preventable, and all farm employees and family members should learn to recognize machine hazards and take precautions to avoid injury.

Machinery Safety

There are many different kinds of agricultural machinery, but they all have similar characteristics and similar hazards. Most have cutting edges, gears, chains, belts, rotating shafts and blades, pinch points, high pressure hoses, and other similar hazards. Many contain multiple hazards of the types just listed. Familiarize yourself with specific hazards associated with all machinery used on your farm. The following information is provided to increase your safety awareness and injury prevention.

- Do not get on or off machinery while the engine is running. Turn the engine off and remove the key before dismounting. Some machinery includes safety devices that turn off the engine or disengage engine power when the operator is not positioned in the seat. These precautionary devices should never be removed or bypassed for any purpose.
- Never attempt to adjust, clean, or unclog any part of a machine while the engine is running.

- Ensure that the operator's manual is on hand and that all operators are familiar with the contents, especially the safe operating procedures.
- Ensure that all machinery operators receive training. Document any safety training provided and be sure to keep these records on file.
- Make sure that equipment is properly maintained and that all safety devices (shielding, guards, etc.) are functioning properly. Never override manufacturer-included safety technologies to save time. Replace or add safety warning labels that are missing or illegible.
- Always wear the appropriate personal protective equipment (PPE) when operating machinery. Refer to the owner's manual for a list of the machine-specific requirements.
- Keep the operator station clean and free from debris, trash, etc.
- Do not allow passengers on the machine at any time for any reason, unless a designated and approved second operator seat is provided by the manufacturer. The "No seat, no rider" rule is always in effect.
- Always wear close fitting clothing with no loose ends or strings that could easily be caught in moving parts.
- Always leave adjustable height components on machinery (front end loaders, combine heads, defoliator units, forklift mast, etc.) in the lowered position when not in use.

Tractor Safety

Tractors are used frequently throughout the year to perform tillage operations, harvesting, planting, spraying, and other operations that have contributed greatly to increasing farm productivity. This frequent use requires that tractor operators must be aware of tractor safety concerns. Tractor rollovers account for more than half of all farm fatalities. A tractor can roll over in any direction: rear, front, or either side. Power take-off (PTO) entanglements and run overs are the other accidents that can occur with tractor use. The following recommended safe work practices are provided to help prevent injuries when operating tractors.

- Ensure that all tractor operators are properly trained. Start with the operator's manual. Document the training provided and be sure to keep records on file.
- Make sure all maintenance requirements are performed as specified by the manufacturer. Perform a visual inspection of the tractor and implement prior to each use.
- Ensure that all tractors are equipped with a rollover protective structure (ROPS) and a seat belt. Always wear the seat belt with a ROPS. Seat belts ensure that the operator stays within the ROPS zone of protection during a tractor rollover. ROPS are not designed to prevent a rollover.
- Limit the use of tractors not equipped with a ROPS. Seat belts should not be used on tractors without a ROPS. A seat belt eliminates the operator's chances of being thrown clear of an overturning tractor.

- Where possible, avoid operating tractors near ditches, embankments, and holes.
- Avoid crossing slopes whenever possible and use appropriate speeds for operating conditions.
- Pay attention, especially at row ends, on highways, and around trees.
- Do not allow others to ride. No seat, no rider.
- Hitch loads only to the drawbar and hitch points recommended by the tractor manufacturer.
- Always start the tractor from the operator's seat. Never bypass start a tractor.
- Always check that all PTO shielding, on the tractor and attached implement, is correctly installed and properly maintained.
- Never attempt to repair, adjust, remove debris, or step over a PTO while it is operating.
- Disengage the PTO, turn the tractor engine off, and remove the key before dismounting to make adjustments, repairs, or remove debris from a PTO driven implement.
- Make sure the tractor and implement have a properly mounted slow moving vehicle (SMV) emblem and front and rear lighting that is clean and in working order.

Preventing and controlling farm hazards and risks is a management issue. Managing farm safety and your health requires a ***proactive attitude*** toward the elimination, prevention, and control of work-related hazards. The information provided is to assist you with generating safer work conditions when operating agriculture machinery. Additional resources on farm safety topics and equipment specific to tobacco can be viewed on the N.C. Department of Labor website (https://www.labor.nc.gov/safety-and-health/agricultural-safety-and-health) or on the Tobacco Growers Information Portal.

11. PROTECTING PEOPLE AND THE ENVIRONMENT WHEN USING PESTICIDES

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Despite their usefulness, agricultural chemicals also pose risk to people and the environment. We need to make choices that minimize these risks. Of particular concern are keeping nutrients and pesticides out of surface water and groundwater and reducing human and wildlife exposure to pesticides. The following sections describe some measures that tobacco producers and professional applicators can take to minimize the threat to people and water quality and reduce pesticide exposure to humans and wildlife.

The U.S. Environmental Protection Agency (EPA) Worker Protection Standard, which was recently updated, regulates actions by employers to protect agricultural workers and pesticide handlers by reducing pesticide exposure and the risk of pesticide-related illness or injury. To protect your employees, you must be aware of the Worker Protection Standard and comply with its requirements, including new requirements effective in January 2017 and 2018. In addition, some tobacco purchasers require that growers comply with Good Agricultural Practices (GAPs) standards, which include worker training and protection standards.

To fulfill the requirements imposed by the Worker Protection Standard, you must protect agricultural workers (who provide hand labor in the production of agricultural plants) and pesticide handlers (who must be at least 18 years old and who mix, load, or apply pesticides or directly come into contact with pesticides through other tasks) in three ways:

1. **Provide training on pesticide safety and information about the specific pesticides used on the farm.** Pesticide safety training should occur before workers and handlers begin working and on an annual basis. Records must be kept of training for each worker and handler for two years. Information that must be posted in a central location includes a safety poster, information about the nearest emergency medical facility, contact information for the North Carolina Department of Agriculture and Consumer Services, specifics on pesticide applications (product name, EPA registration number, active ingredient, crop or site treated,

location of application, date and start and end times of application, and the restricted-entry interval (REI)), and a copy of the safety data sheet (SDS) for pesticides applied. Safety information must also be posted at decontamination sites (see below). Application and safety information must be kept for two years and provided to any worker, handler, medical provider, or designated representative when requested. Handlers must also be given specific information about the instructions provided on a pesticide label.

2. **Ensure protection against exposure.** For handlers, employers must provide personal protective equipment and be sure it is properly used and cleaned, with inspections before use each day and repairs as needed. When the use of a respirator is required on a pesticide label, employers must provide handlers with a medical evaluation to be sure the handler is healthy enough to wear the respirator, training in how to properly use a respirator, and a test to be sure of the respirator's fit. They must also warn workers about pesticide-treated areas (through oral warnings, posting of the Worker Protection Standard warning sign in fields for all pesticides with an REI of more than 48 hours, or both if required by the label). Employers must make sure that workers do not enter treated fields during REIs and that handlers do not apply a pesticide so that it contacts workers or others. Handlers must suspend their application if a worker or other person is in an area up to 100 feet around the application equipment. Protecting against exposure requires careful scheduling of pesticide application and field work so they do not conflict. Personal protective equipment requirements vary from pesticide to pesticide and may be different for applicators/handlers and mixers/loaders. REIs also vary by pesticide and are given on labels. For all pesticide labels, check carefully for specific requirements, even if you have used the product in previous years.
3. **Provide ways for workers to minimize and mitigate impacts of pesticide exposure.** This includes ensuring that decontamination sites and emergency assistance in case of exposure are available. For both workers and handlers, employers must provide easily accessible decontamination supplies within ¼ mile and outside of the treated area or area under an REI; these supplies include water (1 gallon for workers and 3 gallons for handlers), soap, single-use towels, and clean coveralls. Decontamination supplies for handlers must be available where they mix or load pesticides and where they remove their personal protective equipment after handling pesticides. When products require protective eyewear, employers must provide eye wash systems where mixing and loading occurs and water for eye flushing during pesticide applications. In case of pesticide poisoning or injury of a worker or handler, employers must provide transportation to a medical facility and pesticide information to medical personnel.

This chapter does not describe all of the requirements of the Worker Protection Standard, and the following resources can help you comply:

- For a reference guide for the revised Worker Protection Standard, visit https://www.epa.gov/pesticide-worker-safety/pesticide-worker-protection-standard-how-comply-manual
- The Pesticide Educational Resources Collaborative (PERC) website lists all training resources that have been developed for the revised Worker Protection Standard, as well as resources

for employers about how to comply and a quick reference guide: http://pesticideresources.org/wps/inventory.html

- You can find detailed information on the Worker Protection Standard and a link to the entire document here: http://www.epa.gov/agriculture/htc.html
- To help growers comply with Worker Protection Standard and GAP requirements, North Carolina State University provides pesticide applicator training opportunities: http://ipm.ncsu.edu/pesticidesafety/

Table 11-1 lists products, common names, registration numbers, manufacturers, signal words, restricted-entry intervals (REIs), and posting/notification requirements for the major pesticides and growth regulators used in tobacco. This information is presented to help you to properly record and post pesticide use and to plan field operations. However, the information in this table is presented in good faith as a reference and is not an exhaustive list. This information does not take the place of the product label; changes to label information can occur without notice. Always read and follow label directions. The label on the container of the product you are actually using must be followed, even if there has been a change on newer labels.

MINIMIZE PESTICIDE AND FERTILIZER USE WHERE POSSIBLE

Pesticide use should be only one part of an overall pest management program for insects, diseases, suckers, and weeds. It makes good environmental and economic sense to rotate crops, destroy stalks and roots early, use thresholds where available, promote a healthy and vigorous crop with good cultural practices, and fertilize properly. Fertilizer use can also affect pest problems and water quality. Be sure to have your soil tested field by field and to apply only those nutrients recommended. This protects the environment and also saves money by reducing pesticide and fertilizer use. Refer to chapter 5, "Managing Nutrients," for guidelines. Refer to the sections on insect, disease, weed management, and sucker control for proper management of these pests.

SELECT PESTICIDES CAREFULLY

Cultural practices are important parts of a sound pest management program, but pesticides often must still be used to prevent economically significant losses. When this is the case, take care to match the pesticide with the pest. First, identify the pest, and then select an effective pesticide, rate, and application method, carefully considering potential effects on water and safety to humans and wildlife.

A measurement called an LD_{50} is used to measure pesticide toxicity to humans and other mammals. The LD_{50} is the amount of a substance that will cause death in 50 percent of a target population (rats, mice, or rabbits are most commonly used in studies). The lower the number, the more acutely toxic the substance is. An LD_{50} can be used only to measure acute toxicity or

the immediate health effects experienced within the first few days after a brief exposure to a substance. The LD_{50} is not a measure of chronic toxicity or of the long-term consequences (including cancer) resulting from a long time period of exposure. In general, it is best to choose the least toxic pesticide that will do the job. Use extreme caution with pesticides that have low LD_{50} ratings. Note that proper handling of pesticides (including the use of appropriate personal protective equipment) minimizes the risk of acute and chronic effects of all pesticides—even those with low LD_{50} values. Information on acute toxicity can be found in Table 11-1. Information on chronic toxicity can be found on SDS provided by your pesticide dealer. Both the pesticide label and the SDS should be on hand when a pesticide is being used.

APPLY PESTICIDES CAREFULLY

Care must be taken to make sure that pesticides are applied only to the tobacco crop and not the field borders. Field borders consist of ditches, hedgerows, and woods, which are all vital habitat for wildlife. Imprecise application can be detrimental to these areas, and contaminated water in ditches may find its way into larger bodies of water, such as ponds, lakes, and rivers, or into groundwater. Precise application is especially important with aerial pesticide applications. Virtually all pesticides used in tobacco are more effective when applied via ground equipment, and aerial applications are not recommended.

Human exposure to pesticides occurs in one of the following three ways: (1) exposure through the skin or eyes (dermal), (2) exposure through eating, drinking, and other hand-to-mouth behaviors (ingestion), or (3) exposure through breathing vapors and dusts (inhalation). The use of protective clothing and equipment by handlers and applicators is the best defense against exposure to pesticides and is specified on each pesticide label. These requirements should be followed exactly. The potential for harmful pesticide exposure is greater when handling concentrated pesticides (those not mixed with water) than with using a diluted solution (mixed with water in a sprayer). Therefore, be especially careful in the mixing and loading process. For example, pesticides should not be added to a spray tank by lifting the pesticide container above one's head to pour into the tank. If pesticide poisoning is suspected, contact the Carolinas Poison Center at 1-800-222-1222 (http://www.ncpoisoncenter.org/) and seek immediate medical attention, bringing the pesticide label with you. The Carolinas Poison Center provides 24-hour services for diagnosing and treating human illness resulting from toxic substances.

ROTATE PESTICIDE MODES OF ACTION

Applying pesticides with the same mode of action (MOA) more than one time per growing season can increase the risk of pest resistance to these tools. To aid growers in rotating pesticide mode of action, three organizations have developed MOA categories. These codes are listed on pesticide labels: FRAC (Fungicide Resistance Action Committee), IRAC (Insecticide Resistance Action Committee), and WSSA (Weed Science Society of America). When it becomes necessary to treat a tobacco pest with more than one insecticide application (for example, if multiple

tobacco hornworm treatments are required per season), pesticides with different MOAs should be chosen for the applications. Note that pesticide trade names and active ingredients may share the same MOA; for example, acephate (Orthene) and carbaryl (Sevin) are both in IRAC group 1A. Therefore, following a Sevin application with an Orthene application does not represent a pesticide MOA rotation. To assist in chemical selection, FRAC, IRAC, and WSSA codes are listed in Table 11-1.

MINIMIZE SOIL MOVEMENT AND LEACHING

As soil particles become dislodged, they carry pesticides and nutrients that may eventually find their way into a water source. To minimize contamination of our water resources, be sure to follow sound soil conservation practices, such as avoiding unnecessary cultivation and using cover crops, waterways, and strip-cropping. Consult your local Natural Resources Conservation Service and N.C. Cooperative Extension agents for advice.

Pesticides commonly used on tobacco differ in their potential to contaminate surface water and groundwater. Predicting which pesticides may reach groundwater and where this is most likely to occur is very difficult because of differences in soil chemical and physical characteristics and in water table depth. Generally, rolling soils in the piedmont have more potential for surface water contamination through runoff, whereas the porous soils of the sandhills and coastal plain may be more susceptible to groundwater contamination through leaching. However, surface water contamination can occur even on slightly sloping soils in the coastal plain. The Natural Resources Conservation Service can help you determine the leaching and runoff potentials for your fields.

There are also guidelines that help determine which pesticides may be at highest risk for runoff and leaching. Two guidelines for pesticides are *surface loss potential* and *leaching potential*. Surface loss potential is broken into two categories: the risk of a pesticide running out of a field in solution with surface water (rain, irrigation, or flooding) and the risk of a pesticide adhering (being adsorbed) to soil or organic material and washing out of the field as erosion. A high rating in either category means the pesticide has a high tendency to move off the field, while a low rating means the pesticide has a low potential to move. Leaching potential indicates the tendency of a pesticide to move in solution with water and leach below the root zone. These guidelines are based on knowledge of the chemical characteristics of different pesticides and are summarized in Table 11-1. (The symbol "NA" is used where information is not available.) These are general guidelines and should be interpreted as such. Most pesticides will move into either surface or groundwater supplies in at least one of the ways described above. For example, a material that is not very leachable will tend to be adsorbed to soil and move with erosion. Thus, your best choice will depend on the characteristics of the field and the measures you have taken to reduce the chance of runoff.

PROTECT WELLS

Improperly constructed and protected wells offer the quickest pathway for pesticides to reach groundwater (and perhaps your drinking water). Direct flow through wells is most often the source of high levels of pesticide contamination in groundwater. Groundwater contamination is difficult and very expensive to clean up; prevention of such contamination is best. Preventative measures include the following:

- Ensuring that wells are properly constructed and sealed.
- Not mixing or loading pesticides within one hundred feet of a well.
- When filling spray tanks, ensuring the hose or pipe is not at or below the surface of the water in the tank. Otherwise, it is possible to back-siphon the pesticide mixture directly into your water supply.
- Installing back-flow prevention devices, and inspecting them frequently.

Table 11-1. Environmental contamination potential and mammalian toxicity of commonly used tobacco pesticides

Changes to labels can occur at any time. This information does not take the place of the product label. Always read and follow label directions; it is the law.
The footnoted items in Table 11-1 should be interpreted as follows:

[a] Exception to Restricted Entry Interval: If a product is soil-injected or soil-incorporated, under certain circumstances, workers may enter the treated area if there will be no contact with anything that has been treated.

[b] Worker Notification: Unless the pesticide labeling requires both types of notification, notify workers EITHER orally OR by posting warning signs at entrances to treated areas (labeled "Either"). You must inform workers which method of notification is being used. Some pesticide labels require you to notify workers BOTH orally AND with signs posted at entrances to the treated area. If both types of notification are required ("Oral and Written"), the following statement will be in the "Directions for Use" section of the pesticide labeling under the heading Agricultural Use Requirements: "Notify workers of the application by warning them orally and by posting warning signs at entrances to treated areas."

[c] Most common trade names listed; others may be in use as well. Always refer to the label for the product you intend to use.

[d] Surface loss may occur when pesticides go into solution in water and run off the field in surface water. Potentials by Natural Resources Conservation Service, 2004. NA = not available.

[e] Surface loss may also occur when pesticides are adsorbed to soil or organic materials and washed out of the field. Assessment retrieved from the Pesticide Properties Database (https://sitem.herts.ac.uk/aeru/ppdb/en/index.htm). NA = not available.

[f] Leaching occurs when pesticides are moved downward in solution. Assessment retrieved from the Pesticide Properties Database (https://sitem.herts.ac.uk/aeru/ppdb/en/index.htm) and cross referenced with GUS scores via the National Pesticide Information Center (http://npic.orst.edu/envir/gus.html). NA = not available.

[g] LD_{50}: The dose (quantity) of a substance that will be lethal to 50 percent of the organisms in a specific test situation. It is expressed in the weight of the chemical (mg) per unit of body weight (kg). The lower the number, the more toxic the chemical. When more than one LD_{50} for mammals was found in the literature, the lowest found is shown here. "Oral" refers to toxicity through ingestion, while "dermal" refers to toxicity by skin contact. Values are from product MSDS.

[h] Telone C-17 also contains chloropicrin.

* = Technical material. Technical material (pure active ingredient) may be more or less toxic than the formulated material.

NA = not available.

Common Name, EPA Reg. No. & Company Name (for first listed trade name)	Signal Word	Restricted Entry Interval (REI)[a]	Worker Notification[b]	Trade name(s)[c]	Surface Loss Potential (solution)[d]	Potential for particle bound transport[e]	GUS leaching potential index[f]	FRAC, IRAC, or HRAC MOA Grouping	Mammalian LD_{50}[g]	
									Oral	Dermal
1,3-dichloropropene EPA Reg. No. 62719-12 Dow AgroSciences	Danger	5 days	Oral and Written	Telone C-17[h]	Intermediate	Low	Moderate	8B	224	333
									Inhalation danger	
Acephate EPA Reg. No. 5481-8978 AMVAC	Caution	24 hr	Either; all greenhouse applications must be posted	Orthene 97	Intermediate	Low	Low	1A	688*	>2,000*

Table 11-1. *(continued)*

Common Name, EPA Reg. No. & Company Name (for first listed trade name)	Signal Word	Restricted Entry Interval (REI)[a]	Worker Notification[b]	Trade name(s)[c]	Surface Loss Potential (solution)[d]	Potential for particle bound transport[e]	GUS leaching potential index[f]	FRAC, IRAC, or HRAC MOA Grouping	Mammalian LD_{50}[g]	
									Oral	Dermal
Acetamiprid EPA Reg. No. 8033-36-70506 United Phosphorus	Caution	12 hr	Either	Assail	Intermediate	Low	Low	4A	805	>2,000
Acibenzolar-S-methyl EPA Reg. No. 100-922 Syngenta Crop Protection	Caution	12 hr	Either	Actigard	Intermediate	Low	Low	21	> 5,000	> 2,000
Azadiractin EPA Reg. No. 71908-1-10163 Gowan Company	Caution	4 hr	Either	Aza-Direct	NA	NA	NA	UN	> 5,000	> 2,000
Azoxystrobin EPA Reg. No. 100-1098 Syngenta Crop Protection	Caution	4hr	Either	Quadris	NA	Medium	Moderate	11	> 5,000	> 4,000
Bacillus thuringiensis EPA Reg. No. 73049-39 Valent Agricultural Products	Caution	4 hr	Either	Dipel DF	NA	NA	NA	11	> 5,050	> 2,020

Table 11-1. *(continued)*

Common Name, EPA Reg. No. & Company Name (for first listed trade name)	Signal Word	Restricted Entry Interval (REI)[a]	Worker Notification[b]	Trade name(s)[c]	Surface Loss Potential (solution)[d]	Potential for particle bound transport[e]	GUS leaching potential index[f]	FRAC, IRAC, or HRAC MOA Grouping	Mammalian LD_{50}[g]	
									Oral	Dermal
Bifenthrin EPA Reg. No. 279-3302 FMC Corporation	Warning	12 hr	Either	Capture LFR	Low	Medium	Low	3A	54.5	2,000
Butralin EPA Reg. No. 33688-4-400 Chemtura	Danger	12 hr	Either	Butralin	High	Medium	Low	3	891	> 2,000
Carbaryl EPA Reg. No. 61842-37 NovaSource	Warning	12 hr	Either	Sevin XLR Plus	Intermediate	Low	Moderate	1A	500	> 2,000
Carfentrazone-ethyl EPA Reg. No. 279-3241 FMC Corp.	Caution	12 hr	Either	Aim EC	Intermediate	Low	Low	E	4077	>4,000
Chlorantraniliprole EPA Reg. No. 352-729 DuPont Crop Protection	NA	4 hr	Either	Coragen	Low	High	Very Low	28	>5,000	>5,000
Chloropicrin EPA Reg. No. 5785-17 Great Lakes Chemical Corp.	Danger Poison	48 hr	Oral and Written	Ashta Gold	Intermediate	Low	Moderate	8B	NA Inhalation danger	NA

Table 11-1. *(continued)*

Common Name, EPA Reg. No. & Company Name (for first listed trade name)	Signal Word	Restricted Entry Interval (REI)[a]	Worker Notification[b]	Trade name(s)[c]	Surface Loss Potential (solution)[d]	Potential for particle bound transport[e]	GUS leaching potential index[f]	FRAC, IRAC, or HRAC MOA Grouping	Mammalian LD_{50}[g]	
									Oral	Dermal
Chlorpyrifos EPA Reg. No. 62719-591 Dow AgroSciences	Warning	24 hr	Oral and Written	Lorsban	Low	Medium	High	1B	96	2,000
Clomazone EPA Reg. No. 279-3158 FMC Corp.	Caution	12 hr	Either	Command	Intermediate	Medium	High	13	1,369*	> 2,000*
Cyantraniliprole EPA Reg. No. 352-860 DuPont	Caution	4 hr	Either	Verimark	High	Low	Moderate	28	>5,000	>5,000
Dimethomorph EPA Reg. No. 241-427 BASF Corp.	Caution	12 hr	Either	Forum	High	Medium	Moderate	40	3,900*	> 2,000*
Ethephon EPA Reg. No. 264-418 Arysta	Danger	48 hr	Oral and Written	Super Boll	Low	Medium	Low		3,030	1,560
Etridiazole EPA Reg. No. 400-422 Macdermid	Danger	12 hr	Either	Terramaster 4 EC	Intermediate	Low	Low	14F4	1,077	> 5,000
Fatty Alcohols EPA Reg. No. 400-542 Arysta	Danger	24 hr	Either	Off-Shoot-T	NA	NA	NA	NA	28,300	1,750

Table 11-1. *(continued)*

Common Name, EPA Reg. No. & Company Name (for first listed trade name)	Signal Word	Restricted Entry Interval (REI)[a]	Worker Notification[b]	Trade name(s)[c]	Surface Loss Potential (solution)[d]	Potential for particle bound transport[e]	GUS leaching potential index[f]	FRAC, IRAC, or HRAC MOA Grouping	Mammalian LD_{50}[g]	
									Oral	Dermal
Fluensulfone EPA Reg. No. 66222-243 Adama	Caution	12 hr	Either	Nimitz	NA	NA	NA	NA	>2,000	>2,000
Flumetralin EPA Reg. No. 19713-510 Drexel	Caution	12 hr	Either	Drexalin Plus	Low	High	Low	NA	>2,000	>2,000
Fluopicolide EPA Reg. No. 59639-140 Valent	Caution	12 hr	Either	Presidio	NA	Medium	High	43	>2,000	>4,000
Imidacloprid EPA Reg. No. 264-827 Bayer CropScience	Caution	12 hr	Either; all greenhouse applications must be posted	Admire, Provado, Nuprid, many others	High	Medium	High	4A	4,143	> 2,000
Lambda-cyhalothrin EPA Reg. No. 100-1402 Syngenta Crop Protection	Warning	24 hr	Either	Besiege	Low	High	Very Low	3A	98.11	>5,000
Maleic hydrazide EPA Reg. No. 400-84 Chemtura	Caution	12 hr	Either	Several (Royal MH-30 and many others)	Intermediate	Low	Low	NA	> 5,000	> 5,000

Table 11-1. *(continued)*

Common Name, EPA Reg. No. & Company Name (for first listed trade name)	Signal Word	Restricted Entry Interval (REI)[a]	Worker Notification[b]	Trade name(s)[c]	Surface Loss Potential (solution)[d]	Potential for particle bound transport[e]	GUS leaching potential index[f]	FRAC, IRAC, or HRAC MOA Grouping	Mammalian LD_{50}[g]	
									Oral	Dermal
Mefenoxam EPA Reg. No. 100-801 Syngenta Crop Protection	Caution	48 hr	Either	Ridomil Gold	High	Low	Low	4	1,172	> 2,020
Metaldehyde EPA Reg. No. 5481-507 AMVAC	Caution	12 hrs	Either	Deadline Bullets	Intermediate	Low	Low	NA	283	>5,000
Metam sodium EPA Reg. No. 5481-468 AMVAC	Danger	48 hr	Oral and Written	Vapam	Intermediate	Low	Low	Z	812 Inhalation danger	> 2020
Methomyl EPA Reg. No. 352-384 DuPont	Danger Poison	48 hr	Either	Lannate LV	Intermediate	Low	Moderate	1A	17	>2,000
Napropamide EPA Reg. No. 70506-64 United Phosphorus Inc.	Danger	24 hr	Either	Devrinol 2 EC	High	Medium	Moderate	15	4,640	>5,000
Oxamyl EPA Reg. No. 352-532 Orion ATO, LLC	Danger Poison	48 hr	Either	Oxamyl 42	Intermediate	Low	Moderate	1A	9.1	>5,000

Table 11-1. *(continued)*

Common Name, EPA Reg. No. & Company Name (for first listed trade name)	Signal Word	Restricted Entry Interval (REI)[a]	Worker Notification[b]	Trade name(s)[c]	Surface Loss Potential (solution)[d]	Potential for particle bound transport[e]	GUS leaching potential index[f]	FRAC, IRAC, or HRAC MOA Grouping	Mammalian LD_{50}[g]	
									Oral	Dermal
Oxathiapiprolin EPA Reg. No. 100-1571 Syngenta	Caution	4 hr	Either	Orodis Gold 200	NA	High	Low	U15	>5,000	>5,000
Pebulate EPA Reg. No. 10182-158 Zeneca Ag Products	Caution	12 hr	Either	Tillam 6-E	Intermediate	Low	Low	8N	1,400	>2000
Pendimethalin EPA Reg. No. 241-337 BASF Ag Products	Caution	24 hr	Either	Prowl 3.3	Intermediate	High	Low	3	3,956	2,200
Pymetrozine EPA Reg. No. 100-912 Syngenta Crop Protection	Caution	12 hr	Either	Fulfill	NA	Medium	Low	9B	> 5,000	> 5,000
Pyrethrins EPA Reg. No. 1021-1771 MGK Company	Caution	12 hr	Either	Pyganic (multiple formulations)	NA	NA	Low	3A	> 2,000	> 2,000
Sethoxydim EPA Reg. No. 7969-58 BASF	Warning	12 hr	Either	Poast	Intermediate	Low	Low	1	3,200	> 5,000

Table 11-1. *(continued)*

Common Name, EPA Reg. No. & Company Name (for first listed trade name)	Signal Word	Restricted Entry Interval (REI)[a]	Worker Notification[b]	Trade name(s)[c]	Surface Loss Potential (solution)[d]	Potential for particle bound transport[e]	GUS leaching potential index[f]	FRAC, IRAC, or HRAC MOA Grouping	Mammalian LD_{50}[g]	
									Oral	Dermal
Spinosad EPA Reg. No. 62719-267 Dow AgroSciences	Caution	4 hr	Either	Tracer	Low	Medium	Low	5	> 5,000	NA
Sulfentrazone EPA Reg. No. 279-3220 FMC Corp.	Caution	12 hr	Either	Spartan	High	Medium	High	14	2,855*	>2,000*
Thiamethoxam EPA Reg. No. 100-939 Syngenta Crop Protection	Caution	12 hr	Either; all greenhouse applications must be posted	Platinum, T-Moxx, Actara	High	Medium	High	4A	> 5,000	> 2,000

FRED G. BOND SCHOLARSHIPS

for students interested in tobacco

The Fred G. Bond Scholarship Endowment provides scholarships for two- or four-year undergraduate students or for graduate students enrolled in the College of Agriculture and Life Sciences at NC State University. Recipients must be planning to pursue careers in the tobacco industry—specializing in tobacco farming, in corporate or university tobacco research, or in Extension work relating to tobacco production.

Undergraduate applicants from tobacco farms in the southeastern United States have priority in the selection of Bond Scholarship recipients. Scholarships will be awarded to in-state students ($1,500 per year) and out-of-state students ($3,000 per year) and continue as long as the student maintains a "B" average.

The Bond Scholarships are in memory of Fred G. Bond, who served the tobacco industry for 43 years, including 23 years as chief executive officer of the Flue-Cured Cooperative Stabilization Corporation. During his distinguished career, Bond represented flue-cured tobacco growers in the six flue-cured tobacco-growing states in many critical situations, and he provided leadership to numerous tobacco industry, civic, and local political boards and organizations.

APPLICATION PROCEDURE

Students accepted or continuing in the college's two- or four-year undergraduate program or in the graduate program are sent a letter containing the following statement:

The College's scholarship program is a part of our commitment to attract outstanding students. College scholarships are available to entering students based on academic merit as well as financial need. In order to be considered for academic merit scholarships, you need only complete and return a scholarship application, which is available from the Academic Programs Office. Call (919) 515-2614. There is no special application form for the Bond Scholarship.