2025 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 2021, was approved by 94% 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 *2025 Flue-Cured Tobacco Guide* is supported totally by a grant from the North Carolina Agricultural 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 Agricultural Foundation, Inc., Box 7645, Raleigh, NC 27695-7645, or call 919-515-2000.

Visit the NC State Extension Tobacco Producers events calendar for information about upcoming events and meetings: go.ncsu.edu/tobacco-growers-events

NC State Extension Tobacco Growers events calendar

2025

FLUE-CURED TOBACCO

Guide

Prepared by

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Published by

NC State Extension
College of Agriculture and Life Sciences
North Carolina State University

For information, contact the NC State Open Knowledge Center (www.lib.ncsu.edu/department/okc).

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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 local Cooperative Extension personnel with tobacco responsibilities as of November 17, 2024.

COUNTY	NAME	TELEPHONE
Alamance	Dwayne Dabbs	336-570-6740
Alexander	Allison Brown	828-632-4451
Beaufort	Rod Gurganus	252-946-0111
Bertie	Billy Barrow	252-794-5317
Bladen	Matthew Strickland	910-862-4591
Brunswick	Amy Mead	910-253-2610
Caldwell	Seth Nagy	828-757-1290
Carteret	Mike Carroll	252-728-8421
Caswell	Matt Solomon	336-694-4158
Chatham	Dalton Suits	919-542-8242
Chowan	Mary Morris	252-482-6585
Columbus	Lydia Miles	910-640-6606
Craven	Mike Carroll	252-633-1477
Cumberland	Connor Peacock	910-321-6875
Davidson	Troy Coggins	336-242-2081
Davie	Marsha McGraw	336-751-6297
Duplin	Della King	910-296-2143
Durham	John Lyttle	919-560-8757
Edgecombe	Sydney Jalali	252-641-7817
Forsyth	Colleen Church	336-753-6100
Franklin	Matthew Place	919-496-3344
Gates	Paul Smith, Jr.	252-357-1400
Granville	Mikayla Graham	919-603-1350
Greene	Hannah Massengill	252-747-5831
Guilford	Cole Maness	336-641-2413
Halifax	Brandon Pike	252-534-2711
Harnett	Brian Parrish	910-893-7530

COUNTY	NAME	TELEPHONE
Hertford	Dylan Lilley	252-358-7822
Hoke	Greg Huneycutt	910-875-3461
Iredell	Laura Elmore	704-878-3153
Johnston	Bryant Spivey	919-989-5380
Jones	Jacob Morgan	252-448-9621
Lee	Jared Butler	919-775-5624
Lenoir	Jordan Kennedy	252-527-2191
Martin	Lance Grimes	252-792-1621
Montgomery	Emi Briggs	910-576-6011
Moore	Deborah McGiffin	910-947-4650
Nash	Brittany Pendleton	252-459-9810
Northampton	Brandon Pike	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	Mikayla Graham	336-599-1195
Pitt	Jonathan Smith	252-902-1704
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	Zachary Parker	910-592-7161
Scotland	Randy Wood	910-277-2422
Stokes	Matt Lenhardt	336-593-8179
Surry	Ryan Coe	336-401-8025
Vance	Wykia Macon	252-438-8188
Wake	Katherine Williams	919-623-8268
Warren	Matthew Place	252-496-3344
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	Ryan Coe	336-679-2061

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

Jeffrey H. Dorfman
Professor and Extension Economist, Agricultural and Resource Economics

Flue-cured tobacco acreage in the U.S. stabilized in 2020 after falling steadily from 2014 through 2020, and even rising slightly from its low point over the last few years. However, harvested acres in North Carolina in 2024 will be down compared to 2023 due to excess rain from Tropical Storm Debby and Hurricane Helene. With North Carolina producing over half of all flue-cured tobacco in the U.S., a bad harvest here cannot be made up from other states. We expect to see U.S.-harvested acres down 15% in 2024 versus 2023, pounds produced down 18%, and yield down 15%. This is all caused by many areas of North Carolina seeing their yields or harvested acres down by 30% to 40%.

For tobacco farmers who had a good crop in 2024, these circumstances pave the way for higher prices. Pricing power for tobacco growers will likely continue into 2026 as the world supply of high-quality leaves will remain tight due to this year's short harvest in the U.S. and bad weather conditions in southern Brazil and Zimbabwe. With world markets for flue-cured tobacco likely to remain tight through at least 2025, growers in North Carolina can expect very strong prices in 2025 and at least some of that strength to continue into 2026. Prices in the $2.30 to 2.50 range are certainly possible if the quality is there.

These prices will help to offset the recent and probable future increases in the cost of the H-2A guest worker program (luckily the 2025 increase was only 2.2%). Tobacco production costs will continue to rise, likely exceeding $5,000 per acre for many growers. Thus, while tobacco produces a high dollar return per acre, the percentage return on investment can still be lower than for alternative crops. Therefore, even with tobacco's profitability and increased prices, if the costs of the H-2A program continue to increase at the rate they have been, the decline in tobacco acreage is likely to resume.

With the higher prices expected following this year's short crop, planted acres of flue-cured tobaccoin the U.S. and in North Carolina are likely to hold steady or rise slightly in 2025, landing somewhere between 110,000 and 120,000 acres in North Carolina, and 185,000 to 200,000 acres nationwide. Planting will not be so expansive as to lower prices, which will hopefully hold in the $2.30 to 2.40 range. Unfortunately, with production costs for tobacco heavily weighted toward labor, fuel, and chemicals, the only relief on the cost side is likely to be from fuel prices, so profitability may do little more than hold steady. Therefore, the economic outlook for flue-cured tobacco for 2025 looks a lot like 2022 and 2023: solid profits if expected yields are achieved, but only modest improvement in returns compared to last year or this year, unless you had a weather-impacted 2024, in which case a good 2025 will be a nice bounce back from a down year.

Table 1-1. Flue-cured tobacco—machine harvest, hand top—eastern North Carolina: 2025 estimated costs per acre

Budget Category	Budget item	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	8.00	$30.00	$240.00	
	Fertilizer, 6-6-18	lb	667.00	$0.52	$346.84	
	Fertilizer, 15.5-0-0	lb	193.00	$0.33	$63.69	
	9-45-15 Transplant starter	lb	11.00	$1.65	$18.15	
	Lime (prorated)	ton	0.33	$82.00	$27.06	
	Pest control	acre	1.00	$220.74	$220.74	
	Sucker control	acre	1.00	$186.24	$186.24	
	Consulting services**	acre	1.00	$50.00	$50.00	
	Hauling	lb	2,400.00	$0.05	$120.00	
	Cover crop	acre	1.00	$50.00	$50.00	
	Irrigation	cycle	3.00	$13.94	$41.82	
	Curing fuel	gal	275.00	$1.32	$362.73	
	Electricity	kwh	1,250.00	$0.12	$150.00	
	Crop insurance*	acre	1.00	$120.00	$120.00	
	Baling supplies	lb	2,400.00	$0.003	$7.20	
	Tractor/machinery	acre	1.00	$421.99	$421.99	
	Labor, pre-harvest	hr	40.00	$15.81	$632.40	
	Labor, postharvest	hr	5.00	$15.81	$79.05	
	Interest on op. cap.	$	$1,436.99	5.375%	$77.24	
	Total variable costs:				**$3,802.97**	
3. INCOME ABOVE VARIABLE COSTS						
4. FIXED COSTS	Tractor/machinery	acre	1.00	$701.25	$701.25	
	Bulk barn	acre	1.00	$132.58	$132.58	
	Tobacco loading system	acre	1.00	$38.75	$38.75	
	Baler	acre	1.00	$7.50	$7.50	
	Irrigation	acre	1.00	$63.50	$63.50	
	H-2A overhead	acre	1.00	$206.00	$206.00	
	Total fixed costs:				**$1,149.58**	
5. TOTAL COSTS					**$4,952.55**	
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 costs.
*Crop insurance: 75% based premium, no disaster subsidies. Pest control includes insecticides, herbicides, and fungicides.

Prepared by: Derek Washburn—NC State Agricultural and Resource Economics Department, and Matthew Vann—NC State Associate Professor and Tobacco Extension Specialist. For additional budget details, visit go.ncsu.edu/enterprise-budgets.

Table 1-2. Flue-cured tobacco—hand top, hand harvest with machine aid—eastern North Carolina: 2025 estimated costs per acre

Budget Category	Budget Item	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	8.00	$30.00	$240.00	
	Fertilizer, 6-6-18	lb	667.00	$0.52	$346.84	
	Fertilizer, 15.5-0-0	lb	193.00	$0.33	$63.69	
	9-45-15 Transplant starter	lb	11.00	$1.65	$18.15	
	Lime (prorated)	ton	0.33	$82.00	$27.06	
	Pest control	acre	1.00	$220.74	$220.74	
	Sucker control	acre	1.00	$186.24	$186.24	
	Consulting services**	acre	1.00	$50.00	$50.00	
	Hauling	lb	2,500.00	$0.05	$125.00	
	Cover crop	acre	1.00	$50.00	$50.00	
	Irrigation	cycle	3.00	$13.94	$41.82	
	Electricity	kwh	1,125.00	$0.12	$135.00	
	Crop insurance*	acre	1.00	$120.00	$120.00	
	Baling supplies	lb	2,500.00	$0.003	$7.50	
	Tractor/machinery	acre	1.00	$350.85	$350.85	
	Labor, pre-harvest	hr	33.00	$15.81	$521.73	
	Labor, harvest/baling	hr	63.00	$15.81	$996.03	
	Labor, postharvest	hr	3.00	$15.81	$47.43	
	Interest on op. capital	$	$1,654.38	5.375%	$88.92	
	Total variable costs:				**$4,206.75**	
3. INCOME ABOVE VARIABLE COSTS						
4. FIXED COSTS	Tractor/machinery	acre	1.00	$698.35	$698.35	
	Bulk barn	acre	1.00	$132.58	$132.58	
	Tobacco loading system	acre	1.00	$38.75	$38.75	
	Baler	acre	1.00	$7.50	$7.50	
	Irrigation	acre	1.00	$63.50	$63.50	
	H-2A overhead	acre	1.00	$206.00	$206.00	
	Total fixed costs:				**$1,146.68**	
5. TOTAL COSTS					**$5,353.43**	
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 costs.
*Crop insurance: 75% based premium, no disaster subsidies. Pest control includes insecticides, herbicides, and fungicides.

Prepared by: Derek Washburn—NC State Agricultural and Resource Economics Department, and Matthew Vann—NC State Associate Professor and Tobacco Extension Specialist. For additional budget details, visit go.ncsu.edu/enterprise-budgets.

Table 1-3. Flue-cured tobacco—hand harvest, hand top—piedmont North Carolina: 2025 estimated costs per acre

Budget Category	Budget Item	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	8.00	$30.00	$240.00	
	Fertilizer, 6-6-18	lb	667.00	$0.52	$346.84	
	Fertilizer, 15.5-0-0	lb	193.00	$0.33	$63.69	
	9-45-15 Transplant starter	lb	11.00	$1.65	$18.15	
	Lime (prorated)	ton	0.33	$82.00	$27.06	
	Pest control*	acre	1.00	$220.74	$220.74	
	Sucker control	acre	1.00	$186.24	$186.24	
	Consulting services**	acre	1.00	$50.00	$50.00	
	Hauling	lb	2,500.00	$0.05	$125.00	
	Cover crop	acre	1.00	$50.00	$50.00	
	Irrigation	cycle	3.00	$13.94	$41.82	
	Curing fuel	gal	250.00	$1.32	$329.75	
	Electricity	kwh	1,125.00	$0.12	$135.00	
	Crop insurance*	acre	1.00	$120.00	$120.00	
	Baling supplies	lb	2,500.00	$0.003	$7.50	
	Tractor/machinery	acre	1.00	$223.89	$223.89	
	Labor, pre-harvest	hr	48.00	$15.81	$758.88	
	Labor, harvest/baling	hr	76.00	$15.81	$1,201.56	
	Labor, postharvest	hr	3.60	$15.81	$56.92	
	Interest on op. capital	$	$1,816.98	5.375%	$97.66	
	Total variable costs:				**$4,540.70**	
3. INCOME ABOVE VARIABLE COSTS						
4. FIXED COSTS	Tractor/machinery	acre	1.00	$409.44	$409.44	
	Bulk barn	acre	1.00	$132.58	$132.58	
	Tobacco loading system	acre	1.00	$38.75	$38.75	
	Baler	acre	1.00	$7.50	$7.50	
	Irrigation	acre	1.00	$63.50	$63.50	
	H-2A overhead	acre	1.00	$206.00	$206.00	
	Total fixed costs:				**$857.77**	
5. TOTAL COSTS					**$5,398.47**	
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 costs.
*Crop insurance: 75% based premium, no disaster subsidies. Pest control includes insecticides, herbicides, and fungicides.

Prepared by: Derek Washburn—NC State Agricultural and Resource Economics Department, and Matthew Vann—NC State Associate Professor and Tobacco Extension Specialist. For additional budget details, visit go.ncsu.edu/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 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 an I-9 form for every employee hired after 1986. The I-9 must be completed on the first day of employment, or within the first three days of employment if employed for longer than three days. Employers must keep the I-9 either for one or three years 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 U.S. An employer must accept documents that are listed on the I-9 as verification. No employer is 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.

Using E-Verify is mandatory for businesses with more than 25 employees. 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 non-confirmation (TNC). If an employer receives a TNC for an employee, the employer should follow the directions from E-Verify.

E-Verify is not a replacement for the I-9 form and should not be utilized until after an employee has completed the I-9 form. Many rules, regulations, and requirements apply to E-Verify, and employers must understand and abide by all of them. For more information on North Carolina regulations, visit www.labor.nc.gov/workplace-rights/e-verify or 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 by visiting 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 the following requirements:

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

At the time of writing, the estimated 2025 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 is estimated to be $176,100 for 2025. 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 H-2A program. For more information, contact the United States Social Security Administration or visit the agency's website at: 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). Employers should keep copies of both documents. Income taxes on H-2A 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. H-2A 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 was paid only on the first $31,400 of each employee's wages in 2024. The state tax rate is between 0.06% and 5.76%, depending on the credit or debt ratio. The starting rate for new businesses 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 des.nc.gov.

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 H-2A 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 at (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 500 "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 their 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 at 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 may be exempt from overtime if salaried greater than $43,888 per year, effective July 1, 2024. The salary for exemption rises to $58,656 per year effective January1, 2025 (https://www.dol.gov/sites/dolgov/files/WHD/flsa/ot-541-final-rule.pdf).

To make this determination, review federal code CFR 541 at www.ecfr.gov/current/title-29/subtitle-B/chapter-V/subchapter-A/part-541?toc=1.

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 aged 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 aged 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 at (919) 814-3650, or visit the program's website: www.ncdot.gov.

JOINT EMPLOYMENT

"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, 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

In general, agricultural employers are subject to the Migrant and Seasonal Agricultural Worker Protection Act (MSPA) if they employed 500 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 at (866) 4-USA-DOL, or visit the department's MSPA compliance site at www.dol.gov/agencies/whd/agriculture/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, and must obtain the appropriate authorization certificates to house and transport laborers and drive transportation. To inquire about the validity of a certificate, call (866)-4-US-WAGE (866-487-9243).

An employer must be on the preauthorization H-2A application to use H-2A workers provided by a crew leader (H-2ALC 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 unit(s) and notify the North Carolina Department of Labor 45 days before any workers arrive. Housing units 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 (800) 625-2267 or obtain the registration form online at 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 water with individual cups

POSTER REQUIREMENT

Certain North Carolina employers are required to place government posters that explain employees' rights in conspicuous places. 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 posters from companies that are selling them. Not all operations will be covered by the same statutes; requirements vary by individual business. To determine which poster(s) you are required to display, visit www.labor.nc.gov/safety-and-health/publications/state-and-federal-workplace-poster-requirements.

NEW HIRE REPORTING

North Carolina employers are required to report the names, addresses, Social Security numbers, dates of birth, and dates of employment for all new employees to the state government. Employers are also required to report their own 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 ncnewhires.ncdhhs.gov. 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 at (800) NC-LABOR or www.labor.nc.gov.

NEW LAWS AND REGULATIONS

Additions to the 2025 handbook beyond typical figure updates: Changes in labor law are being proposed at the time of this writing (September 2024). All producers are encouraged to stay informed about changes that may occur before this guide is published again.

NOTES

3. SELECTING A VARIETY

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According to a recent survey, NC 960 was the most popular variety of flue-cured tobacco planted in North Carolina during 2024. NC 960 was grown on 21% of the tobacco acres in the state. Other popular varieties were NC 196 (18%), K 326 (15%), CC 145 (13%), CC 143 (11%), GL 365 (7%), PVH 1920 (3%), and NC 1226 (2%). Figure 3-1 shows the most popular varieties planted since 2017. To select the right variety for your fields, consider the information produced during variety testing at a research station in your area.

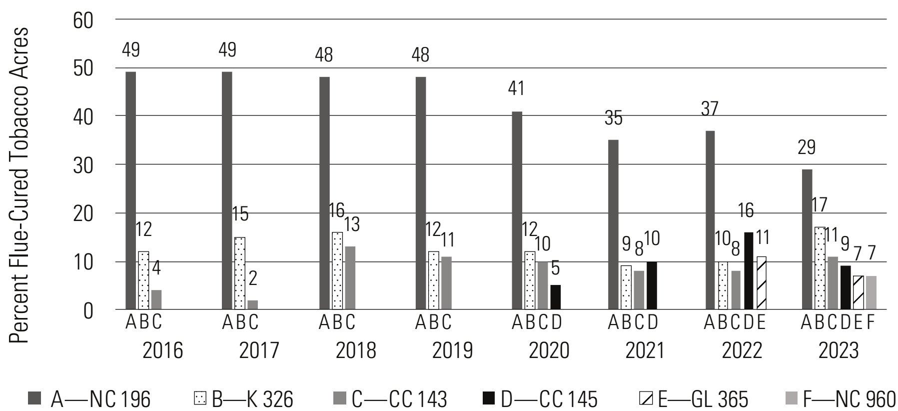

Figure 3-1. N.C. Cooperative Extension agent estimates of plantings of several popular varieties, 2016–2023

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. After 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 five locations, three of which are in North Carolina. A breeding line that passes the RFT, which includes a smoke test, is eligible for release as a commercial variety.

The OVT assist growers with variety selection at these research stations:

1. Lower Coastal Plain Research Station—Kinston
2. Upper Coastal Plain Research Station—Rocky Mount
3. 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.

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 Table 3-1 and the two-year average shown in Table 3-2, are better than single-year data (Table 3-3).

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 and individual location data (Tables 3-4, 3-5, and 3-6) are helpful when you need 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, 2022, 2023, and 2024

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.
CC143	3160	4195	134.33	69	63	21.6	40	1.84	19.84	2.38	8.34
CC145	2986	3826	129.42	66	63	21.0	41	1.94	19.22	2.48	7.75
CC603	2945	3835	131.73	67	64	21.8	39	1.80	19.97	2.49	8.02
CC607	3018	4055	134.27	68	63	21.3	40	1.88	18.94	2.34	8.09
CC700	2827	3769	132.99	67	60	20.5	38	1.86	18.26	2.68	6.81
CC1063	2838	3838	134.94	68	63	20.9	40	1.89	18.15	2.65	6.84
GF318	2887	3734	129.25	66	61	21.4	40	1.88	19.77	2.52	7.83
GL26H	3081	3931	127.87	66	63	21.1	39	1.86	20.86	2.45	8.53
GL365	3051	3946	132.65	67	68	22.8	39	1.69	19.31	2.54	7.61
GL386	2908	3778	129.68	66	62	20.7	40	1.95	19.61	2.60	7.54
GL395	2832	3745	131.51	66	61	21.0	39	1.86	18.38	2.77	6.65
K326	3122	4132	133.03	67	61	21.3	38	1.80	20.62	2.44	8.46
NC299	3032	4001	130.90	66	63	21.4	39	1.81	19.35	2.59	7.46
NC606	2878	3879	134.83	68	63	20.3	40	1.97	20.21	2.60	7.77
NC960	3160	4104	130.97	66	65	21.2	41	1.93	19.49	2.35	8.29
NC991	3328	4419	131.52	67	63	20.6	39	1.89	20.29	2.30	8.83
NC993	3306	4227	129.47	66	65	21.5	39	1.81	19.57	2.28	8.59
NC996	3404	4343	128.18	66	63	20.0	41	2.03	20.70	2.44	8.49
NC1226	3078	3916	128.70	65	65	21.4	39	1.82	18.30	2.47	7.40
PVH1920	2888	3729	129.98	66	64	22.2	39	1.76	18.89	2.54	7.44
PVH1940	2606	3527	136.41	69	62	20.9	38	1.83	14.82	2.96	5.00
PVH2254	3089	3986	128.80	65	63	21.6	41	1.90	19.89	2.32	8.58

Table 3-1. *(contnued)*

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.
PVH2310	2781	3814	136.88	69	62	20.7	40	1.94	17.13	2.43	7.06
PVH2343	3093	3989	127.35	64	63	21.7	41	1.88	19.18	2.28	8.42
Test Average	3013	3948	131.53	67	63	21.2	40	1.87	19.22	2.49	7.75
PVH2343	3061	4784	158.48	77	65	20.6	41	1.97	18.83	2.44	7.71
Test Avg.	3057	4649	153.02	75	64	20.2	39	1.94	19.18	2.59	7.42

Table 3-2. Performance of commercial varieties in the North Carolina Official Variety Test, two-year average, 2023 and 2024

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.
CC143	2938	3638	126.69	65	59	21.3	39	1.86	20.44	2.29	8.94
CC145	2816	3416	124.26	63	60	20.4	41	2.00	19.41	2.42	8.02
CC603	2828	3471	126.32	64	61	21.5	39	1.83	20.07	2.49	8.07
CC607	2795	3572	129.33	64	59	20.8	40	1.90	19.06	2.25	8.46
CC700	2643	3322	126.47	63	57	19.9	38	1.89	18.41	2.56	7.19
CC1063	2644	3351	129.80	65	60	20.2	40	1.98	18.42	2.45	7.51
GF318	2702	3252	122.19	62	57	20.7	40	1.92	20.51	2.37	8.67
GL26H	2847	3476	126.22	64	59	20.3	39	1.91	21.31	2.50	8.53
GL365	2894	3715	131.07	66	64	22.4	38	1.70	19.23	2.53	7.61
GL386	2855	3518	125.30	64	59	20.3	40	1.98	19.72	2.55	7.74
GL395	2591	3196	124.67	63	57	20.2	39	1.94	18.40	2.71	6.78
K326	2893	3694	129.35	65	55	20.9	38	1.80	21.15	2.38	8.89

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.
K346	2502	3144	129.27	64	61	19.9	38	1.92	18.85	2.35	8.01
NC196	2884	3662	129.67	65	61	20.9	40	1.93	20.46	2.45	8.34
NC299	2913	3525	123.81	62	60	20.6	39	1.88	19.66	2.52	7.79
NC606	2690	3467	130.33	65	60	19.7	40	2.01	20.50	2.59	7.90
NC960	3032	3699	124.47	62	64	20.8	40	1.95	19.95	2.29	8.73
NC991	3002	3699	123.62	62	60	20.2	38	1.90	20.22	2.34	8.63
NC993	3135	3772	124.69	62	62	21.3	38	1.80	19.85	2.18	9.11
NC996	3281	3992	122.38	62	59	20.0	41	2.06	21.12	2.40	8.80
NC1006	3264	3927	124.80	63	59	20.0	40	2.02	20.43	2.24	9.12
NC1007	3169	3895	127.75	64	60	19.8	42	2.11	20.14	2.32	8.68
NC1226	2895	3441	122.45	62	62	21.0	38	1.83	18.83	2.35	8.00
PVH1920	2699	3406	131.08	66	60	21.6	39	1.79	19.01	2.49	7.62
PVH1940	2501	3296	133.41	66	59	20.4	39	1.92	14.93	2.78	5.37
PVH1980	2667	3344	129.06	65	58	20.5	38	1.86	16.61	2.38	6.98
PVH2233	3171	3926	126.27	64	63	22.0	40	1.82	20.75	2.07	10.01
PVH2254	2914	3509	121.95	61	59	21.0	40	1.92	19.62	2.33	8.42
PVH2310	2664	3528	135.79	67	58	20.0	40	2.00	17.21	2.31	7.44
PVH2343	3005	3578	121.59	61	60	21.0	40	1.92	19.97	2.13	9.36
PXH53	3008	3703	125.84	63	60	20.6	39	1.91	20.00	2.57	7.79
Test Average	2866	3553	126.77	64	60	20.7	39	1.91	19.49	2.41	8.15

Table 3-3. Performance of commercial varieties in the North Carolina Official Variety Test, combined over three locations, 2024

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.
CC143	3127	3346	108.44	57	56	22.4	41	1.84	20.04	2.19	9.16
CC145	3055	3294	109.27	57	54	21.8	43	1.97	18.61	2.30	8.09
CC603	3104	3369	110.01	57	58	22.7	41	1.82	20.02	2.28	8.79
CC607	2911	3290	114.62	59	56	21.9	41	1.89	18.67	2.10	8.89
CC700	2722	3055	112.94	57	53	21.3	39	1.83	17.76	2.39	7.43
CC1063	2871	3179	111.67	57	57	21.5	42	1.94	17.62	2.26	7.81
GF318	2839	2917	103.07	53	54	22.2	42	1.88	19.88	2.22	8.95
GL26H	3119	3355	111.13	58	57	22.0	40	1.82	19.53	2.58	7.58
GL365	3123	3551	114.79	59	60	24.1	40	1.65	18.29	2.41	7.59
GL386	3031	3166	105.42	56	55	21.4	42	1.96	19.50	2.41	8.09
GL395	2707	2963	110.12	56	55	21.4	41	1.93	17.38	2.64	6.57
K326	3013	3288	109.37	56	53	22.4	40	1.78	20.87	2.19	9.53
K346	2658	2830	109.06	56	57	21.1	40	1.91	18.79	2.20	8.54
NC71	3281	3445	106.22	55	57	21.8	39	1.77	19.38	2.53	7.65
NC196	3164	3557	112.96	58	54	22.2	43	1.93	20.10	2.37	8.49
NC299	3196	3381	106.07	54	55	22.0	41	1.84	19.31	2.19	8.82
NC606	2794	3166	114.29	58	56	21.0	42	1.98	20.32	2.60	7.82
NC960	3178	3193	102.02	52	60	21.5	42	1.94	19.77	2.14	9.22
NC991	3009	3278	110.29	56	57	21.2	39	1.86	19.79	2.27	8.70
NC993	3161	3251	105.56	55	59	22.5	40	1.77	18.67	2.00	9.33
NC996	3437	3418	99.91	52	56	20.8	43	2.05	20.61	2.22	9.27

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.
NC1006	3393	3661	109.29	57	53	20.9	41	1.97	19.91	2.19	9.09
NC1007	3303	3438	110.30	56	57	20.9	43	2.06	19.81	2.20	9.01
NC1111	3313	3599	110.88	57	55	21.4	41	1.90	21.01	2.43	8.65
NC1113	3227	3396	106.22	55	58	21.5	40	1.88	20.24	2.19	9.25
NC1226	3132	3191	103.99	54	59	22.1	40	1.82	17.94	2.10	8.54
PVH1920	2821	2973	110.38	56	55	22.7	40	1.77	18.84	2.33	8.08
PVH1940	2607	2950	113.72	59	56	22.2	41	1.83	14.28	2.64	5.40
PVH1980	2727	3044	111.82	58	53	22.4	41	1.82	16.22	2.36	6.89
PVH2233	3332	3629	110.80	57	60	23.1	41	1.79	20.32	1.88	10.82
PVH2254	3058	3143	103.34	53	57	22.7	42	1.86	18.15	2.36	7.70
PVH2310	2766	3222	116.86	60	54	21.5	42	1.96	16.93	2.09	8.11
PVH2343	3184	3209	102.43	53	58	22.2	42	1.88	19.11	2.00	9.56
PXH53	3256	3577	111.12	58	58	21.6	40	1.87	19.07	2.58	7.40
PXH70	3161	3566	113.23	58	58	21.6	41	1.90	20.00	2.40	8.33
Test Average	3051	3282	109.19	56	56	21.9	41	1.88	19.05	2.29	8.38
RJREX608	2251	3543	156.23	75	70	19.3	35	1.81	18.63	2.52	7.4
RJREX609	2363	3473	147.25	73	63	18	37	2.05	20.55	2.43	8.45
Test Avg.	2622	3997	152.47	75	64	18.81	37	1.95	20.38	2.59	7.9

Table 3-4. Performance of commercial varieties in the North Carolina Official Variety Test, Kinston, NC, 2024

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.
CC143	3213	3622	113.27	60	53	20.2	40	1.97	19.03	2.53	7.51
CC145	3251	3915	120.60	63	53	20.1	43	2.12	21.25	2.50	8.50
CC603	3073	3534	115.93	60	54	20.2	40	1.97	19.27	2.67	7.22
CC607	3025	3794	125.43	64	52	19.7	40	2.03	17.30	2.60	6.65
CC700	2707	3552	131.00	67	52	19.3	38	1.95	18.80	2.67	7.05
CC1063	3090	3512	113.57	59	53	20.6	41	1.98	17.93	2.57	6.99
GF318	3015	3469	115.93	60	52	21.4	41	1.94	20.13	2.30	8.75
GL26H	3213	3380	105.77	56	53	20.3	40	1.96	20.03	3.00	6.68
GL365	2963	3568	120.33	62	57	22.5	38	1.67	18.77	2.73	6.87
GL386	2687	3174	117.77	62	54	19.8	40	2.04	16.40	2.70	6.07
GL395	2907	3542	122.17	63	53	19.9	42	2.10	18.07	3.00	6.02
K326	3306	4049	122.33	62	53	21.1	40	1.92	22.67	2.40	9.44
K346	2772	3156	114.10	59	53	20.1	40	2.01	20.20	2.40	8.42
NC71	3355	3792	112.83	59	53	20.4	38	1.88	21.07	3.10	6.80
NC196	3177	3868	121.70	63	54	20.8	42	2.02	21.77	2.50	8.71
NC299	3347	3935	117.63	61	54	20.0	40	1.98	18.70	2.90	6.45
NC606	2776	3604	130.00	65	52	20.1	42	2.07	20.33	2.97	6.85
NC960	3580	3812	105.97	56	54	20.5	41	2.01	20.40	2.17	9.42
NC991	3298	3954	119.90	61	53	20.6	40	1.96	21.37	2.43	8.78
NC993	3042	3409	112.73	58	56	21.7	38	1.73	19.77	2.27	8.72
NC996	3349	3591	106.53	61	52	19.6	41	2.11	23.33	2.27	10.29
NC1006	2867	3353	117.70	62	54	19.6	40	2.05	20.26	2.60	7.79
NC1007	3548	3839	121.17	62	54	19.7	43	2.17	19.43	2.47	7.88
NC1111	3308	4163	125.73	64	52	20.3	40	1.95	19.93	2.87	6.95

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.
NC1113	3391	3934	115.83	60	53	20.4	39	1.91	21.30	2.40	8.88
NC1226	3328	3796	114.70	60	55	20.5	40	1.94	17.83	2.57	6.95
PVH1920	2807	3380	120.53	62	52	21.1	39	1.84	19.97	2.63	7.58
PVH1940	2751	3188	116.20	60	53	20.1	40	1.98	14.60	2.73	5.35
PVH1980	2942	3419	116.33	61	52	20.0	41	2.04	18.00	2.53	7.11
PVH2233	3568	4353	122.27	63	57	21.3	42	1.96	21.70	1.93	11.22
PVH2254	3052	3527	115.50	61	53	21.1	42	1.99	19.73	2.02	9.76
PVH2310	3027	3747	124.03	64	53	20.1	43	2.12	19.40	2.07	9.39
PVH2343	3135	3339	106.03	54	53	20.8	41	1.99	19.03	2.17	8.78
PXH53	3244	3990	123.13	63	52	20.6	40	1.94	19.13	2.90	6.60
PXH70	3162	3593	113.47	59	54	21.3	41	1.91	22.30	2.50	8.92
Test Average	3122	3653	117.66	61	53	20.5	40	1.98	19.69	2.54	7.87
RJREX608	2015	2969	147.8	72	68	18.9	31	1.66	18.73	2.67	7.02
RJREX609	2267	3052	136.13	69	59	17.1	34	1.98	20.23	2.47	8.2
Test Avg.	2515	3661	145.86	73	60	18.51	34	1.84	20.12	2.86	7.1

Table 3-5. Performance of commercial varieties in the North Carolina Official Variety Test, Oxford, NC, 2024*

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.
CC143	2534	3130	123.40	64	-	24.6	47	1.93	19.23	1.90	10.12
CC145	2539	3234	126.53	65	-	23.1	47	2.03	16.57	2.13	7.77
CC603	2770	3459	124.40	63	-	25.0	48	1.93	20.57	1.87	11.02
CC607	2501	3289	131.47	68	-	23.0	46	1.98	16.50	1.97	8.39
CC700	2573	3229	125.27	65	-	23.7	45	1.88	15.47	2.37	6.54
CC1063	2369	2868	122.07	63	-	22.6	45	1.97	14.69	2.20	6.68
GF318	2645	2958	111.97	57	-	23.7	47	2.00	19.00	2.17	8.77
GL26H	3104	3733	120.03	62	-	23.5	45	1.91	20.03	2.27	8.84
GL365	2965	3903	131.53	68	-	25.9	44	1.71	15.37	2.20	6.98
GL386	2742	3291	119.97	62	-	23.5	49	2.07	19.50	2.20	8.86
GL395	2440	3063	125.53	65	-	22.7	46	2.04	14.53	2.33	6.23
K326	2644	3088	117.37	61	-	23.5	41	1.74	17.60	2.23	7.88
K346	2180	2786	127.67	66	-	22.2	45	2.01	15.60	1.87	8.36
NC71	2892	3550	122.83	63	-	23.2	42	1.83	16.93	2.20	7.70
NC196	3071	3843	125.63	65	-	23.3	47	2.01	18.23	2.23	8.16
NC299	2929	3487	118.90	62	-	24.1	45	1.85	18.00	1.97	9.15
NC606	2572	3121	121.10	63	-	21.7	45	2.09	18.83	2.43	7.74
NC960	2520	3000	118.87	60	-	22.3	45	2.01	18.00	2.03	8.85
NC991	2531	3197	126.67	66	-	22.8	44	1.92	15.70	2.06	7.61
NC993	2682	3286	122.40	63	-	23.3	44	1.90	14.73	1.87	7.89
NC996	3647	3752	114.10	60	-	22.4	48	2.13	14.50	2.33	6.21
NC1006	3313	3943	119.20	62	-	21.6	44	2.05	18.67	2.03	9.18

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.
NC1007	2672	3372	125.83	64	-	21.9	50	2.29	18.13	2.17	8.37
NC1111	2793	3494	125.27	64	-	21.8	45	2.07	19.43	2.20	8.83
NC1113	2685	3299	122.87	64	-	22.9	47	2.05	17.27	2.13	8.09
NC1226	2546	3077	120.90	63	-	23.6	44	1.85	15.53	1.93	8.03
PVH1920	2448	2840	127.69	66	-	23.0	44	1.92	16.40	2.23	7.34
PVH1940	2319	2960	126.67	64	-	23.9	45	1.88	11.80	2.33	5.06
PVH1980	2470	2785	112.83	59	-	24.7	45	1.82	12.47	2.37	5.27
PVH2233	2620	3236	123.40	63	-	23.5	43	1.81	17.33	2.17	8.00
PVH2254	2842	3265	114.80	58	-	24.4	47	1.92	14.83	2.47	6.01
PVH2310	2324	2778	120.17	62	-	22.1	45	2.04	12.70	2.10	6.05
PVH2343	2704	3199	118.27	61	-	22.9	45	1.96	18.97	2.07	9.18
PXH53	2990	4516	133.37	68	-	23.7	46	1.94	18.10	2.30	7.87
PXH70	3024	3574	118.90	61	-	21.9	44	2.02	17.27	2.40	7.19
Test Average	2703	3303	122.51	63	-	23.2	45	1.96	16.81	2.16	7.84
RJREX608	2486	4630	164.67	81	72	19.7	39	1.95	18.53	2.37	7.83
RJREX609	2459	3894	158.37	77	67	18.8	40	2.11	20.87	2.4	8.69
Test Avg.	2741	4360	158.87	77	67	19.03	39	2.08	20.53	2.33	8.88

*Plots were topped once (7/29/24) prior to the arrival of Hurricane Debby to prevent lodging, subsequent topping events not recorded.

Table 3-6. Performance of commercial varieties in the North Carolina Official Variety Test, Rocky Mount, NC, 2024

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.
CC143	3741	3430	90.18	49	62	22.5	36	1.62	21.93	2.43	9.01
CC145	3374	2733	80.67	42	59	22.0	39	1.76	20.07	2.27	8.85
CC603	3469	3113	89.70	47	59	23.0	38	1.66	20.23	2.30	8.80
CC607	3206	2785	86.97	45	60	23.0	38	1.67	22.20	1.73	12.81
CC700	2886	2384	82.57	40	54	20.7	35	1.67	19.00	2.13	8.91
CC1063	3155	3156	99.37	50	60	21.2	40	1.90	19.97	2.00	9.98
GF318	2856	2323	81.30	40	55	21.5	37	1.71	20.50	2.20	9.32
GL26H	3041	2951	96.90	50	60	22.1	35	1.59	18.53	2.47	7.51
GL365	3442	3182	92.50	47	63	23.9	37	1.56	20.73	2.30	9.01
GL386	3349	2628	78.53	38	56	20.9	37	1.78	22.60	2.33	9.69
GL395	2774	2283	82.67	41	56	22.6	36	1.58	19.53	2.60	7.51
K326	2999	2651	88.90	46	53	22.6	36	1.59	22.33	1.93	11.55
K346	3021	2550	85.40	43	61	20.9	35	1.69	20.57	2.33	8.81
NC71	3594	2992	83.00	42	64	21.7	35	1.61	20.13	2.30	8.75
NC196	3243	2962	91.53	46	54	22.4	39	1.76	20.30	2.37	8.58
NC299	3313	2722	81.67	40	56	22.1	38	1.71	21.23	1.70	12.49
NC606	3034	2773	91.77	47	60	21.3	38	1.78	21.80	2.40	9.08
NC960	3435	2768	81.23	40	65	21.9	39	1.79	20.90	2.23	9.36
NC991	3164	2593	82.30	41	61	20.3	34	1.68	22.62	2.37	9.56
NC993	3759	3057	81.53	43	61	22.3	38	1.68	21.50	1.87	11.52
NC996	3664	2911	79.10	40	60	20.5	39	1.92	21.77	2.07	10.53
NC1006	3601	3270	90.97	48	55	21.5	39	1.82	20.77	1.93	10.74

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.
NC1007	3688	3101	84.10	43	59	21.1	41	1.97	19.63	1.97	9.98
NC1111	4185	3139	81.63	43	58	22.0	37	1.70	23.67	1.93	12.24
NC1113	3648	2911	78.23	41	62	19.0	35	1.86	22.17	2.03	10.90
NC1226	3523	2702	76.37	39	62	22.1	37	1.68	20.88	2.10	9.94
PVH1920	3255	2736	82.43	42	59	23.5	37	1.58	20.17	2.13	9.45
PVH1940	2750	2701	98.30	52	60	22.5	37	1.65	16.43	2.57	6.40
PVH1980	2769	2927	106.30	55	54	22.4	36	1.63	18.20	2.17	8.40
PVH2233	3807	3297	86.73	45	63	23.9	40	1.65	21.93	1.53	14.30
PVH2254	3279	2637	79.73	41	63	22.6	38	1.68	20.15	1.87	10.78
PVH2310	2948	3142	106.37	55	55	22.3	39	1.73	18.70	2.10	8.90
PVH2343	3714	3088	83.00	44	63	22.9	39	1.71	19.33	1.77	10.94
PXH53	3533	2721	76.87	38	64	20.5	36	1.73	19.97	2.53	7.88
PXH70	3298	3532	107.33	55	62	21.7	38	1.76	20.43	2.30	8.88
Test Average	3329	2881	87.03	44	59	21.9	37	1.71	20.60	2.15	9.75

Table 3-7. NC State University post-buyout grade index and 2024 price index

Company Buying Grade	USDA Grade	Post-Buyout Grade Index (1–100)	2021 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

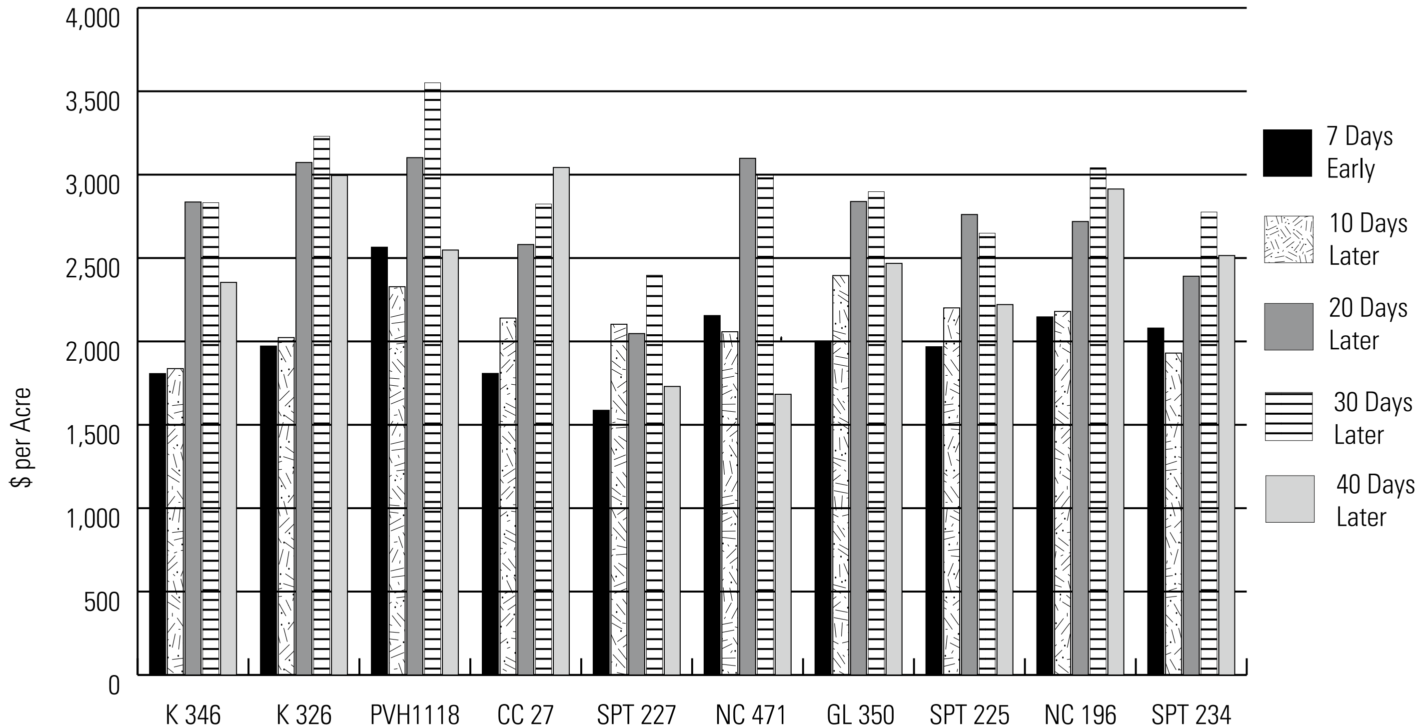

Figure 3-2. Effect of harvest schedule on the value of last priming, 2008

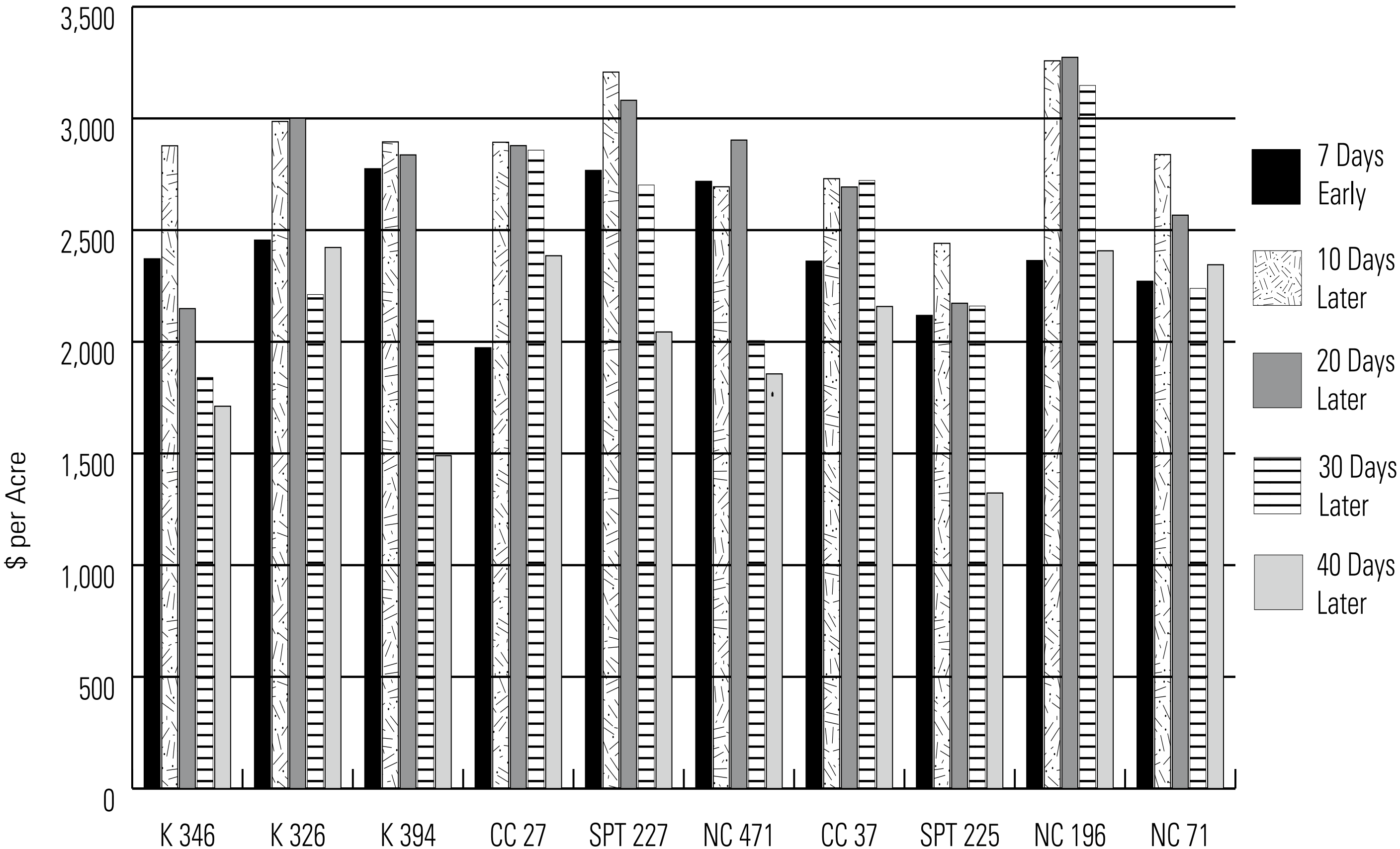

Figure 3-3. Effect of harvest schedule on the value of last priming, 2009

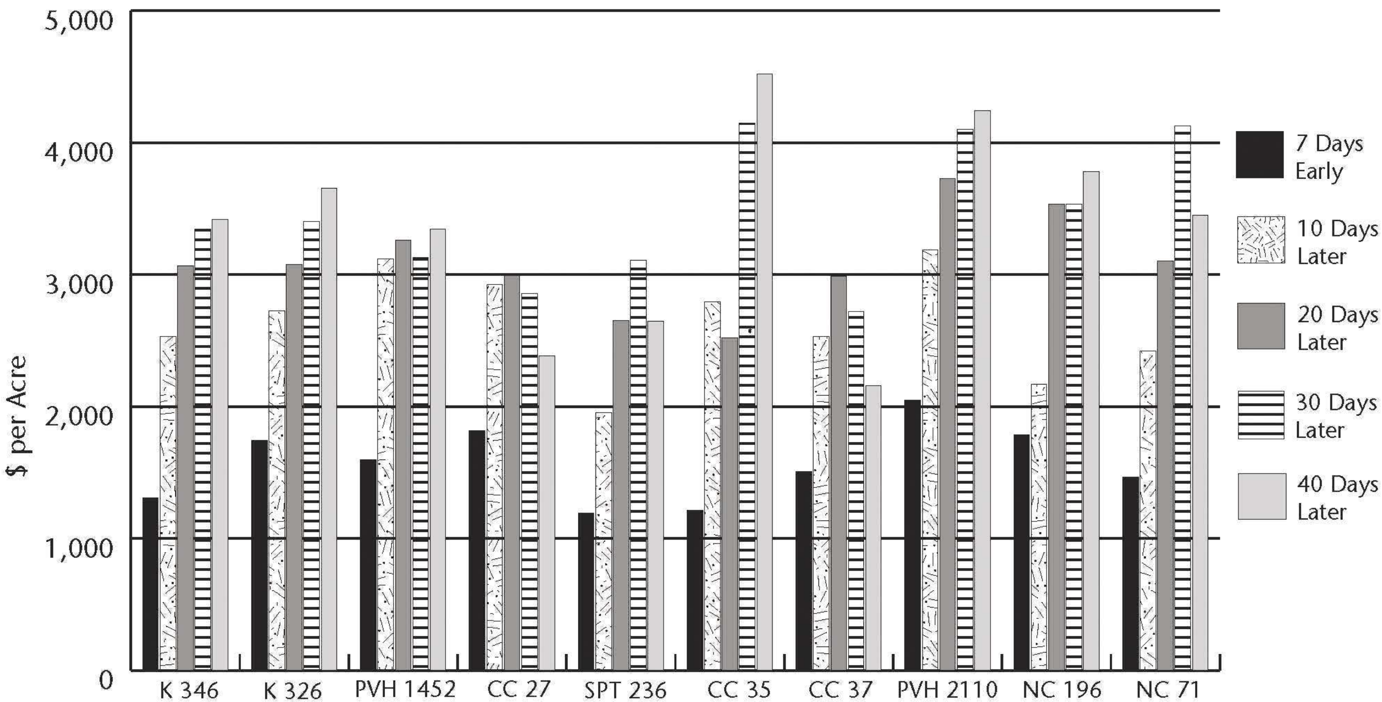

Figure 3-4. Effect of harvest schedule on the value of last priming, 2010

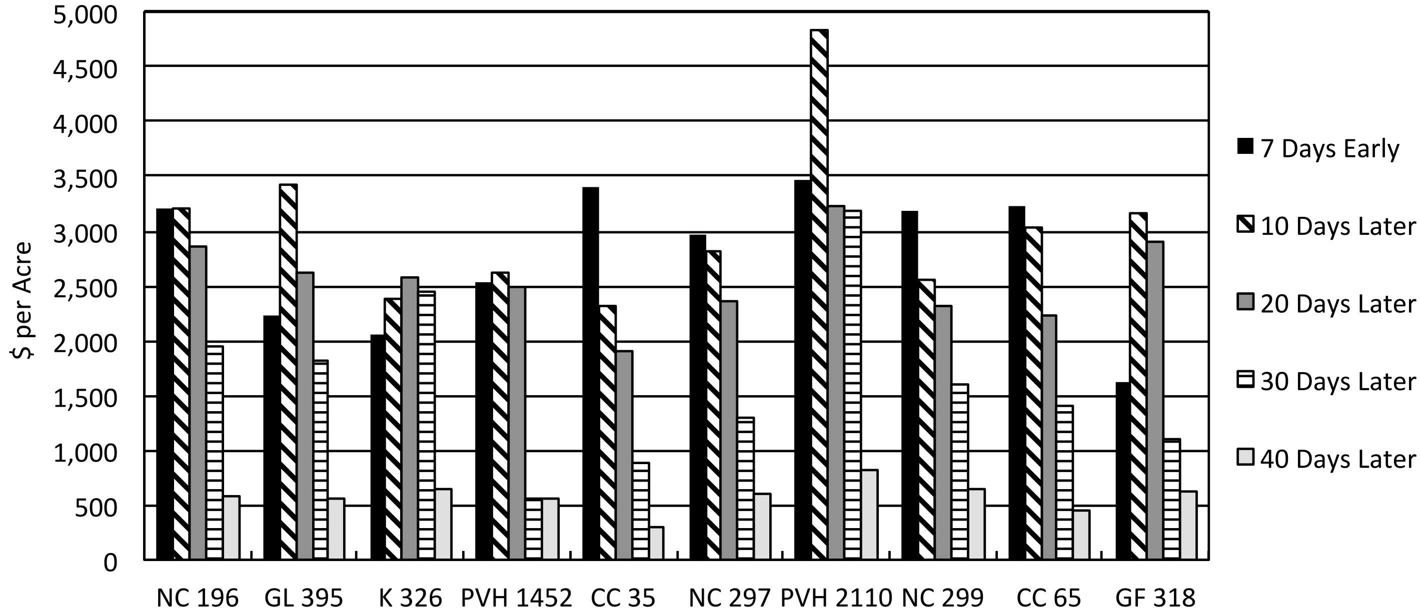

Figure 3-5. Effect of harvest schedule on the value of last priming, 2011

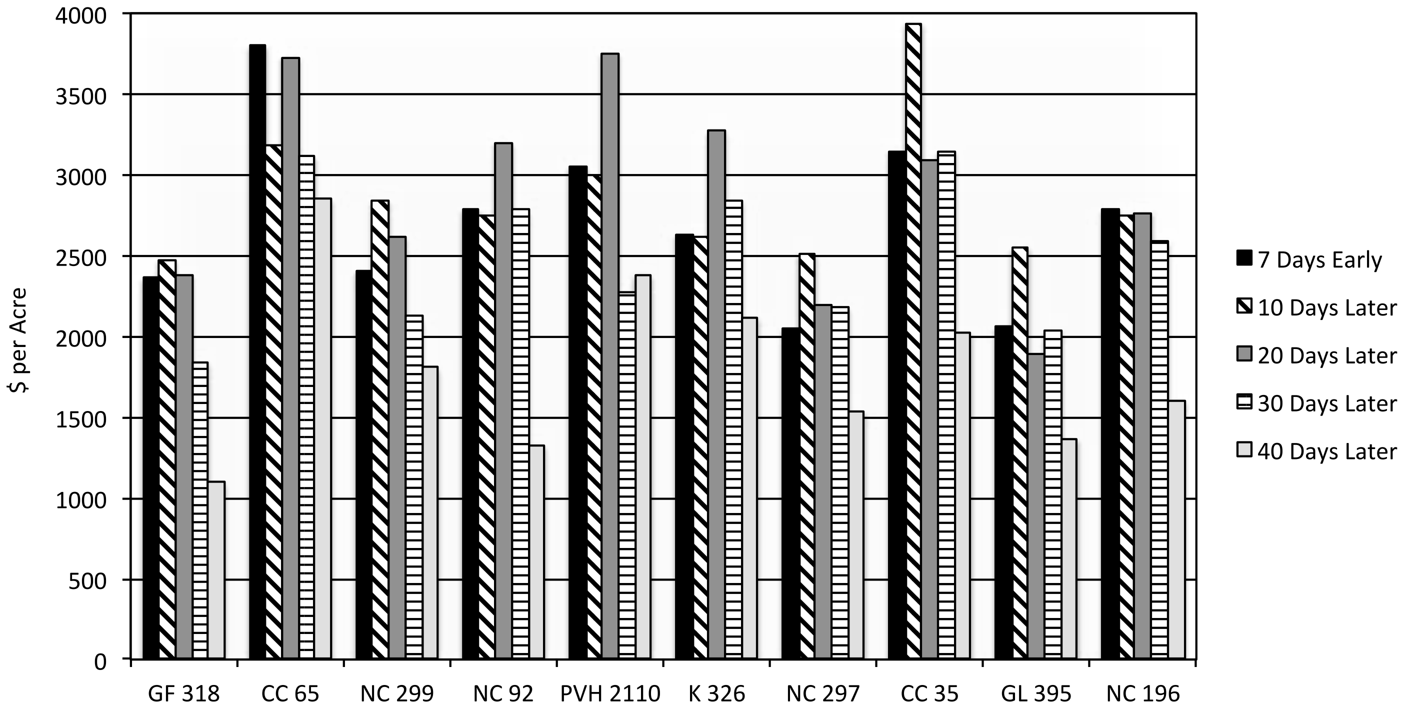

Figure 3-6. Effect of harvest schedule on the value of last priming, 2012

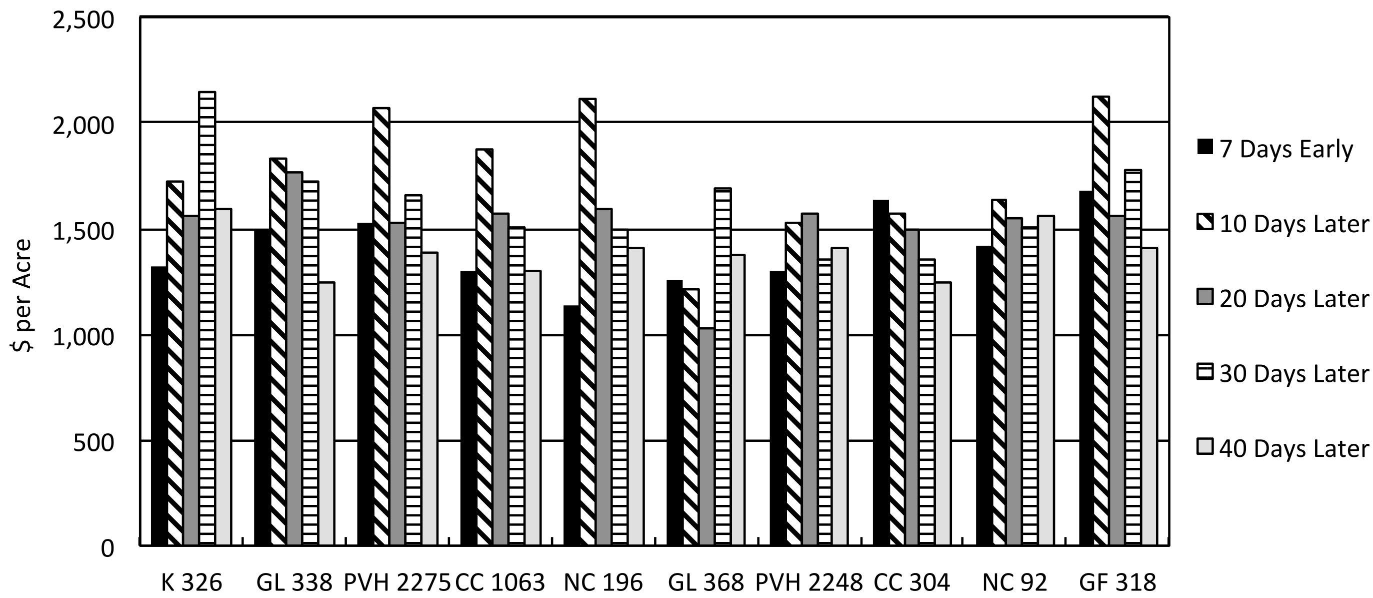

Figure 3-7. Effect of harvest schedule on the value of last priming, 2013

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. For growers producing their own transplants, potential cost savings begin in the greenhouse, where the first step in minimizing cost is to avoid seeding too early, thus reducing the amount of heating fuel consumed. Most growers have learned that it takes only 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 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 will decrease production costs. Nearly all management practices affect usability, but here 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 the tray design and the age of reused trays.
    - 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).
    - Allow greenhouse temperature to fluctuate between 68°F and 86°F but do not maintain a constant temperature.
    - Control ants and mice.

3. Promote uniform growth and prevent stand loss:

- 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.
- Provide proper ventilation and airflow to prevent heat injury.
- Avoid early seeding, high nitrogen rates, and hot daytime temperatures that promote stem rot diseases.
- Pasteurize trays with steam 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 (plastic) drink bottle with a screw-on cap is an excellent sample bottle. Rinse the bottle several times (but do not use soap) and allow the water source to run for several minutes before collecting the sample. Forms and assistance are available from local N.C. Cooperative Extension centers.

When the total alkalinity of the source water is greater than 100 ppm or 2 meq/L, sulfuric acid is applied to the float bed at a rate prescribed by most laboratories. The goal of applying sulfuric acid is not to completely neutralize 100% of the alkalinity, but rather to neutralize the concentration to no more than the concentrations referenced above. Typically, one application of sulfuric acid prior to seeding float trays is sufficient for normal seedling growth. In 2024, a shortage of 35% concentrate v/v sulfuric acid was reported by tobacco seedling producers in multiple states. Alternatives to sulfuric acid are available but are not recommended without consideration for their neutralizing properties and nutritional contributions. If you experience issues obtaining sulfuric acid in 2025, please contact your local Extension agent to discuss these alternatives.

Municipal water sources may also contain elevated concentrations of chloride (Cl-), which can be detrimental to seedling development. When using municipal water sources, growers should inquire as to when Cl- treatment will be applied to mitigate contamination. Avoid pond or river water unless it comes from a municipal source due to potential contamination with disease-causing organisms. Herbicides that injure tobacco could also be carried by soil runoff into farm ponds.

Salt water intrusion along coastal areas into deep wells is a growing concern in North Carolina. Salt water intrusion can be noted by elevated levels of sodium (Na) and chloride (Cl) that are detected in a source water analysis. The individual concentration of either nutrient in float bed source water should not exceed 70 ppm, otherwise an alternative water source should be used

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 and root 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. Fertilizer charge should be minimized to reduce the chance of salt injury.

Consider Tray Design

A significant factor that affects tray cost is the cost of fuel. High natural gas prices have increased the cost of manufacturing trays, 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. 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%. 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:

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

Category	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. This 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

Category	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% of the seedlings could reduce usability (Table 4-3). The researchers seeded random cells within a tray three, five, seven, and 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 uneven growth from delayed emergence.

Table 4-3. Effect of staggered seedling emergence on transplant production

Year	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 uniformly filled with medium.

Wet the new trays before filling them, and screen the planting medium for 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. In addition to a lack of germination, dry cells create another problem in float systems, particularly with new trays. Trays with dry cells will float higher than old trays. Additionally, it is difficult to prevent the medium from falling through the hole in the bottom of a dry cell.

Provide a Warm Temperature

The ideal germination temperature for tobacco seeds is approximately 68°F at night and 86°F during the day, with the temperature fluctuation between day and night being critical. Fuel use decreases 15% for every five-degree reduction in temperature. Therefore, after maximum seedling emergence has occurred, 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 temperature inside the structure exceeds 110°F.

Different varieties respond in various ways to germination temperature, and it is very common to see differences in germination rates among varieties in the same greenhouse. The responses of three popular varieties to temperature during germination is shown in Figures 4-1 through 4-6. In all varieties, germination occurred earlier at 68°F at night and 86°F during the day than at 68°F at night and 95°F during the day. However, the delay in germination from high day 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 at night and 86°F during the 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 seeds from the Official Variety Testing Program found that most varieties reached maximum germination in seven to eight days when exposed to ideal temperatures. However, the range among varieties was from six to 13 days. The germination of most varieties was delayed by one day when the daytime temperature was increased from 86°F to 95°F. However, the germination of NC 71 was delayed by two days (from nine to 11 days).

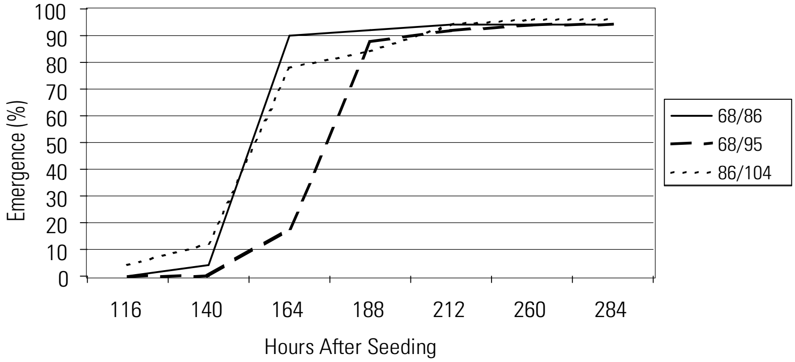

Figure 4-1. Effect of temperature on the germination of K 326, First Evaluation

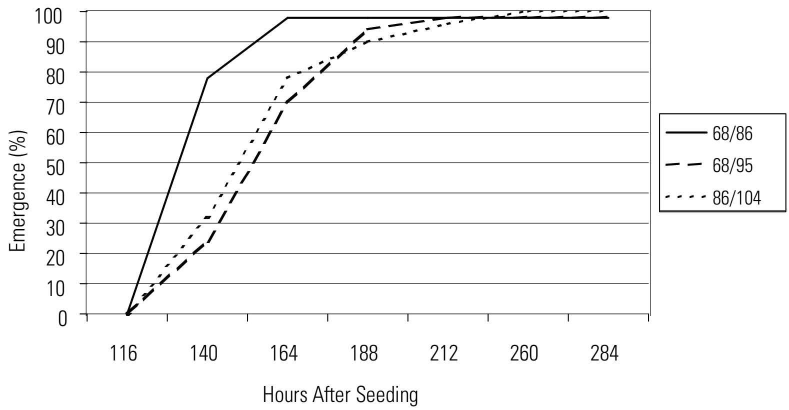

Figure 4-2. Effect of temperature on the germination of K 326, Second Evaluation

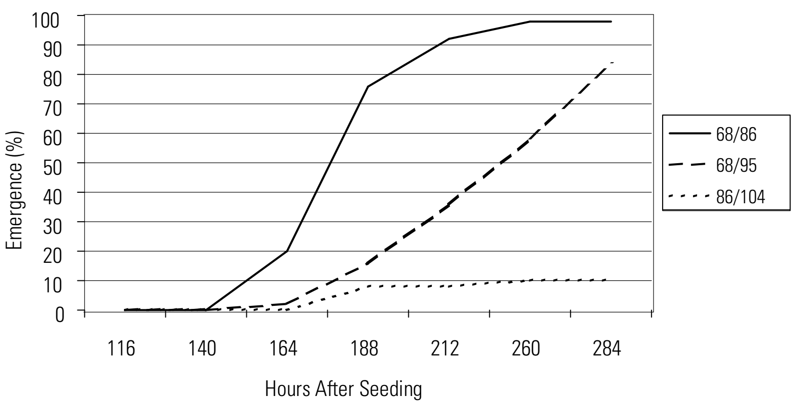

Figure 4-3. Effect of temperature on the germination of NC 71, First Evaluation

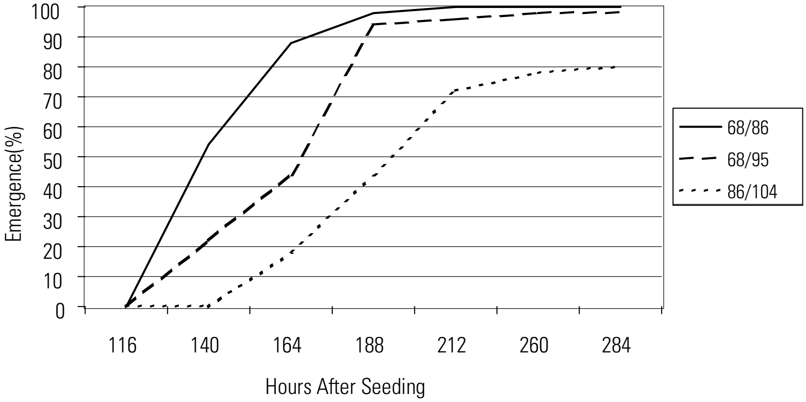

Figure 4-4. Effect of temperature on the germination of NC 71, Second Evaluation

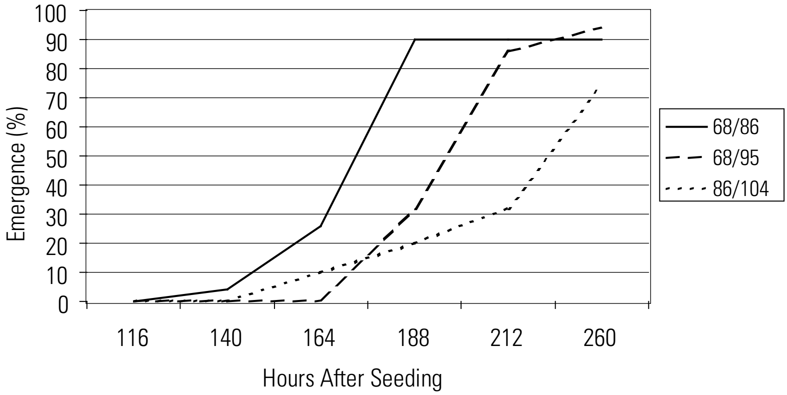

Figure 4-5. Effect of temperature on the germination of NC 297, First Evaluation

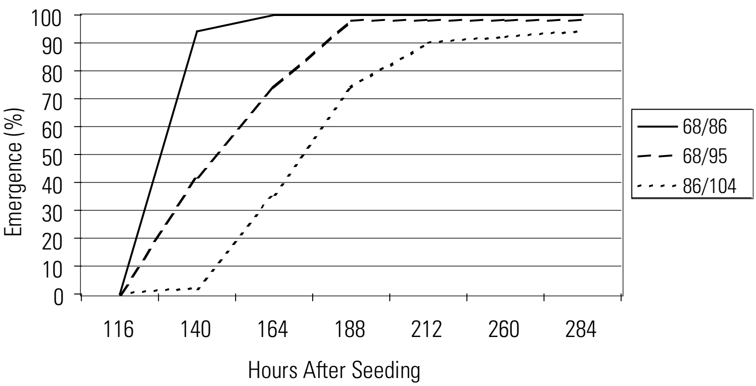

Figure 4-6. Effect of temperature on the germination of NC 297, Second Evaluation

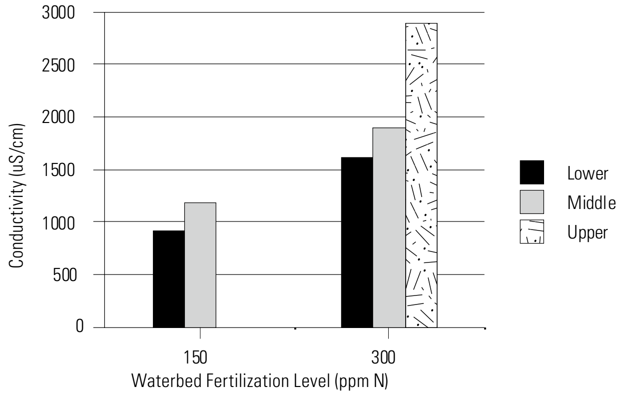

Figure 4-7. Conductivity of a soilless medium at two fertilization levels and at three depths in the cell

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. The nutrients then 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.

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, while 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

Fertilize properly in two application timings. Research has shown that excellent transplants can be obtained from an initial application of fertilizer to supply 100 to 150 ppm nitrogen within seven to 10 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 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.

Seedling producers are strongly encouraged to apply the initial fertilizer application no later than 10 days after seeding. Commercial greenhouse media that is blended for tobacco seedling production contains minimal concentrations of NPK starter fertilizer, which are quickly exhausted after seed germination. Delaying the initial fertilizer application to between 14 and 21 days after seeding will result in slowed, stunted, or irregular plant growth.

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; Figure 4-8). Therefore, as the season progresses and plants absorb 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 obtain an accurate measure of the concentrations of all nutrients in the waterbedthe only way to obtain an accurate measure of the concentrations of all nutrients in the waterbed.

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. 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

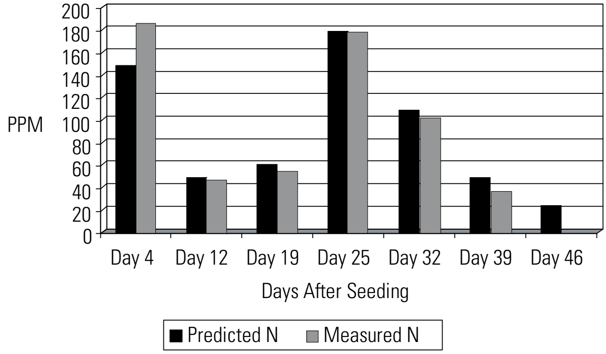

Figure 4-8. A comparison of predicted (based on conductivity) and measured nitrogen concentrations in a float bed

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 does not contain sulfur, or a sulfur deficiency is observed, add Epsom salts to the waterbed at a rate of 4 ounces per 100 gallons of water.

Boron. It has been observed in several float systems that boron deficiency causes bud distortion and death. In most of these cases, neither the water nor the fertilizer contained any boron. If your source water analysis indicates no boron, the best solution is to choose a fertilizer such as a 20-10-20 with a guaranteed micronutrient charge. If a fertilizer with boron is unavailable, adding no more than 0.25 ounces of Borax per 100 gallons of float water should prevent a deficiency.

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). This is very different from the traditional pounds per acre or pounds per plant bed. The following formula is a useful way to calculate the amount of fertilizer necessary for a given concentration in the waterbed.

Where:
Fertilizer added per 100 gallons = amount of fertilizer (in ounces) 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.

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

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

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

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 inches 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 2 to 2.5 inches above the tray and blade height at one to 1.5 inches above the bud. This procedure provides the best balance of uniformity, stem length, and disease management.

Tray Sanitation

If trays are to be reused from the previous season, it is critical to steam trays at 176°F for 30 minutes to reduce the potential carryover of disease-causing organisms. Do not use bleach to clean trays, as it can damage transplants if not sufficiently rinsed from the trays. Be mindful of storage locations for trays when not in use, and avoid potential contact with anything that might cause damage to seedlings, such as herbicides. Additional tray sanitation recommendations can be found in the Managing Disease chapter of this guide.

ADDITIONAL RESOURCES

Producing Conventional Tobacco Transplants in Greenhouses—Water Quality:
go.ncsu.edu/tobacco-water-quality

Cold Injury and Boron Deficiency in Tobacco Seedlings: go.ncsu.edu/tobacco-seedling-cold-boron

NOTES

5. MANAGING NUTRIENTS

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For the past 20 years, fertilizer prices have increased in cost. Prices were very high from 2008 through 2009 as a consequence of the U.S. financial crisis (Figure 5-1). After 2010, fertilizer prices fell before a new small spike around 2012. After that, nitrogen prices slightly declined until 2020. In 2021, fertilizer prices skyrocketed because of an energy crisis in China. The problem worsened in 2022 due to the war between Russia and Ukraine. This shows that fertilizer costs can significantly impact agricultural costs and are highly sensitive to the global economy and politics.

Figure 5-1. Average price of nitrogen, 2003–2022. Source: Bloomberg

Although the cost of fertilizing tobacco has increased significantly, the good news is that there is a wide range in the costs of fertilization programs. Some programs offer significant savings without sacrificing yield or quality (Table 5-1). Research conducted in the 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, comparing 32% UAN (25% nitrate, 75% ammonium), ammonium nitrate (50% nitrate, 50% ammonium), and calcium nitrate (100% nitrate) to supply all of the nitrogen to the crop (Table 5-2). Studies conducted at research stations near Oxford and Kinston (both in North Carolina) showed that yield and quality were not affected by nitrogen source at any location during any year of the study. Additional studies confirm these findings (Table 5-3) and demonstrate the usability of a wide range of nitrogen fertilizer sources.

The bottom line on ammonium versus nitrate is that under our state's growing conditions, nitrification is rapid enough that UAN products containing 75% 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 their decision on factors such as application technology and cost as crop response is generally not an issue.

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

- Use UAN products, such as 24S, 28, 30, or 32%, for at least the sidedress application if not the entire nitrogen program. See treatments 5, 6, and 7 in Table 5-1 and treatments 1 and 2 in Table 5-3.
- Do not apply more phosphorus than recommended from the soil test. More than 90% of the soil test reports from tobacco fields in the coastal plain and 50% from fields in the piedmont recommended avoiding any fertilizer containing phosphorus. Growers reluctant to completely avoid using 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 5-3). An increase in cured leaf yield or quality is very unlikely from transplant water containing phosphorus; however, early season vigor may be improved. Producers should exercise extreme caution when considering a transplant water fertilizer source, as many have not been tested by Cooperative Extension. Contact your local Extension agent for guidance.
- Research in North Carolina also indicates that rates of applied potassium can be reduced to 75 pounds of K2O 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 long as it is 30 days before transplanting on soils with characteristics like those previously mentioned. This alternative approach to potassium fertility works

extremely well with production systems where 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 a blend), to supply all 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, no more than 5 pounds of phosphorus in the transplant water are 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 in production systems that included coarse soil textures, low potassium indices, or excessive rainfall.

- Avoid products that add cost without improving profitability. For example, phosphorus enhancers may be useful under conditions of limited soil phosphorus to improve soil phosphorus availability. However, phosphorus levels in most of our tobacco fields are very high. According to previous studies, there is no advantage to including one of these enhancers (such as Avail) in the fertilizer for tobacco produced in fields with typical soil phosphorus levels (Table 5-4). Limited research in North Carolina and other tobacco-growing states likewise suggests that microbial additives (such as beneficial bacteria and fungi) to production systems do not add significant value.

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

	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	91 a	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	93 a	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	91 a	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	92 a	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	86 a	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	86 a	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	91 a	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	91 a	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	89 a	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	91 a	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 (lb/a)	Quality	Price ($/lb)	Value ($/a)	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.

Table 5-3. Effect of fertilizer programs on cured leaf yield, quality, and value

Program	Yield (lb/a)	Quality	Value ($/a)	Yield (lb/a)	Quality	Value ($/a)
6-6-18 fb. 28-0-0	2,696 a	66 a	3,622 a	2,717 a	89 a	5,138 a
28-0-0 + 0-0-50 fb. 28-0-0	2,841 a	64 a	3,554 a	2,731 a	89 a	5,226 a

Treatment results followed by the same letter within a column should be considered similar.
Quality assessed on a scale of 0–100, with 100 being the highest quality.
fb. indicates that fertilizer was sidedress-applied four weeks after transplanting.

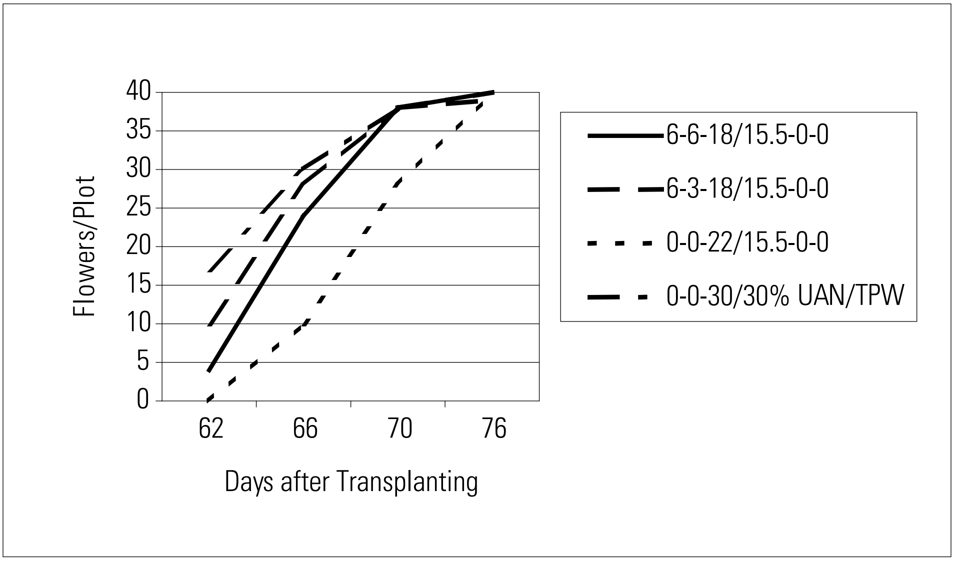

Figure 5-2. Effect of phosphorus application on flowering rate at the Upper Coastal Plain Research Station

Table 5-4. Effect of fertilizer treatment on tobacco yield, grade index, price, and value at two North Carolina locations

Treatment	Cunningham Research Station			Oxford Tobacco Research Station		
	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 NCDA&CS 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), potassium (K), 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. Nitrogen (N) is not included in the soil test, as any N remaining in the soil from the previous growing season will be lost due to North Carolina's typically wet winters.

The nutrient rates indicated on the soil test report reflect only what is found in the sample. Therefore, each sample should be taken properly so that it adequately represents the field where the crop is to be grown. A description of adequate soil sampling procedures can be found on the NCDA&CS Agronomic Services webpage (www.ncagr.gov/agronomi/sthome.htm). Soil sample reports from fields regularly tended 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 local 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 is toxic for plants and reduces root growth and development. Therefore, liming to promote healthy root systems improves drought tolerance and nutrient absorption, and sometimes results 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 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 5-5). 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 application rates are possible when acid soils are limed according to soil test suggestions.

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

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

Table 5-6. Effect of nitrogen rate on tobacco yield and value at the Lower Coastal Plain Experiment Station

Nitrogen Rate (lb/a)	Year One		Year Two		Year Three	
	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 (Tables 5-4 and 5-6).

3. Apply 20 to 30 pounds of sulfur per acre on deep, sandy soils. Sulfur application recommendations are also 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, 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 in advance during 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 riskier 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 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 5-7. 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 onto the row middles, which reduces 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 are also 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 5-7. 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 in. to clay	1 in.	0	0	0
	2 in.	20	10	0
	3 or more in.	30	20	0
10 to 16 in. to clay	1 in.	30	20	0
	2 in.	45	30	10
	3 or more in.	60	40	15
17 or more in.	1 in.	50	25	15
	2 in.	75	35	20
	3 or more in.	100	45	25

[a] Apply about 1 lb of potassium (K_20) for each pound of nitrogen used as a leaching adjustment if the topsoil is deeper than 10 in.

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% magnesium and 11% 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 in the roots followed by root decay will begin unless the saturated condition is alleviated within about 24 hours. Usually, the plants turn 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 5-8; the results are the 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% liquid nitrogen fertilizers increased yield and value by about 10%, and the 15-0-14 and 8-0-11 fertilizers increased yield and value by about 15%. 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% liquid nitrogen fertilizers that supplied only nitrogen. None of the fertilizers improved grade index or average market price compared to the control.

Table 5-8. Effects of fertilizer additions on yield and value of partially drowned tobacco[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 5-9 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 5-9. Effects of nitrogen rate adjustments on yield and value of partially drowned tobacco

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% 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 increased problems with hornworms and aphids. Nitrogen is also very leachable, and overapplication may contribute to groundwater contamination in deep, sandy soils.

Because nitrogen is very leachable, the 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 5-10. 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% or more humic matter.

Table 5-10. 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.

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 and potassium. Phosphorus is not leachable, even in sandy soils, and a good tobacco crop only removes about 15 pounds per acre (as P_2O_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% 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. In contrast, the benefits of phosphorus starter fertillzers in the transplant water are unlikely to be observed when transplanting conditions are warm and dry. Producers should only use transplant water fertilizer materials that have been tested by Cooperative Extension to ensure they are safe for application.

Potassium is leachable, especially in deep, sandy soils, and a good crop removes about 90 pounds per acre (as K_2O). However, about 60% 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 5-11). 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 5-11. 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 of the tobacco plant for the nutrient. However, it is likely that producers can reduce total potassium input by as much as 10% to 20% 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 of clay (Table 5-12). In addition, 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 of K_2O per acre to prevent nutrient depletion within the soil profile.

Table 5-12. Tobacco yield and quality response to increasing rates of applied potassium [a,b]

Rate [c] (lbs K_2O/acre)	Yield (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; however, the overall message is still valid: potassium rates can be reduced without having a negative impact on crop growth and development. In areas marked by deep, sandy soil types, a split application of potassium (half the full rate before or just after transplanting and half 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 similar or smaller amounts than the primary nutrients, and, in general, they are present in lime and some N-P-K fertilizers. However, they must be available in adequate amounts for good yields and quality.

Calcium (Ca) and magnesium (Mg). The most common source of these nutrients is dolomitic limestone. 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 Ca and 15 to 20 pounds of Mg per acre are needed from the other fertilizers. 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 that contain 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 soil test summaries show that just over 25% 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 does occur, 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 of Ca per acre. In this study, leaf yield did not increase 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 (with more than 15 inches to clay) that are low in humic matter (less than 0.5%). Because sulfur leaches, deficiencies are more likely in these soils after 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 turn 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 because the topsoil is sampled and analyzed, but if present, sulfur accumulated in deeper clay layers can be used by plants. 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 5-11) and will be absorbed as roots reach this depth.

Micronutrients

The soil test report from NCDA&CS 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 applications 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, over-limed 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% 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 the 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 3 pounds per acre banded, 10 pounds per acre broadcast, or half a 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 following the recommended rates. Suggested rates of most fumigants also supply adequate amounts of chloride as chlorine; when Telone II or chloropicrin products are 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 pounds per acre were recently evaluated. Cured leaf yield and value were not affected; however, cured leaf quality was reduced when more than 50 to 60 pounds of Cl were 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 of 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 are not always reliable and that tissue sampling should be utilized for diagnosis.

Boron (B). Deficiencies of boron have been documented in North Carolina. There are several 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 half a pound 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 local Extension agent if you suspect you had a micronutrient problem in 2024 or if your soil test indicates that a problem might occur in 2025. 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 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 specified device and can be used offline.

WEBLINKS TO ADDITIONAL NUTRIENT DEFICIENCY INFORMATION

Nitrogen (N): go.ncsu.edu/nitrogen-deficiency

Phosphorus (P): go.ncsu.edu/phosphorus-deficiency

Potassium (K): go.ncsu.edu/potassium-deficiency

Calcium (Ca): go.ncsu.edu/calcium-deficiency

Sulfur (S): go.ncsu.edu/sulfur-deficiency

Magnesium (Mg): go.ncsu.edu/magnesium-deficiency

Boron (B): go.ncsu.edu/boron-deficiency

Manganese (Mn): go.ncsu.edu/manganese-deficiency

NOTES

6. MANAGING WEEDS

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Effective weed management is necessary for profitable tobacco production. If left uncontrolled, weeds can reduce yield, increase the chances for disease, and interfere with management practices including harvest. Furthermore, weed seed and debris can contaminate cured leaf, which decreases quality and overall crop price. A sound weed management plan in tobacco includes crop rotation, cultivation, early stalk and root destruction, hand-weeding, and chemical control. A healthy, rapidly growing plant can be aided 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 (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 inches or over) 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 multi-year North Carolina study, 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 under or equal to 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 attributed to a reduction in soil resistance and compaction.

Where producers are using an injection shank for in-row fumigant application or a ripping shank when bedding, soil resistance and compaction are likely to be minimal—that is, in-row ripping shanks can replace a bottom plow if the goal is to reduce soil resistance and compaction. Producers should note that if soils are excessively moist during tillage activities, the benefits of these practices for 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 effectively controlled 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
Crowfoot grass	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
Lambs quarters	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% to 90%.
F = Fair control, 60% to 80%.
P = Poor control, 1% to 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 4F and Spartan Charge (and other generic versions of sulfentrazone) as well as Tillam are all labeled for nutsedge control. Spartan 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 oz 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 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 provides season-long control of nutsedge and better grass control than Tillam. However, there are significant rotational restrictions on the Spartan label for cotton and sweetpotatoes. 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 is the only herbicide labeled for tobacco that will control morningglories' preemergence. Although control of morningglories is more consistent when Spartan 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 the “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-Spartan Charge or Tillam for improved grass control (compared to Spartan 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, broadcast and incorporate the Prowl before bedding to comply with the current label, then apply Spartan 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, 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 and quality are not significantly reduced. However, control measures should still be employed to reduce seed bank contribution and to prevent contamination of harvested and cured leaf.

Redroot Pigweed and Palmer Amaranth

These large, aggressive weeds can grow as tall as tobacco and interfere with harvest. Spartan 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, 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 the "Herbicide Application Post-directed Prior to Layby or After First Harvest" section below.) Redroot and Palmer must be smaller than 4 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 actually 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 local Extension agents can help with identification. Also, always read the label before purchasing an herbicide to see if the product controls the problem weed, to determine the proper rate, and to be aware of rotational restrictions. Producers should also verify that herbicides are approved for use by contracting companies.

Spartan 4F and Spartan Charge

Spartan 4F has been the formulation for sulfentrazone commonly 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 to occur 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% when Spartan 4F was applied PRE-T compared to 3% to 31% 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 a 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 the beds down to transplanting height and apply the herbicides to the soil surface. For best results, knock the beds down 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 additional soil off 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 and 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 season-long control of annual grasses as well as Command does. 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 sweetpotatoes. 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 a 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

Aim can be applied using a shielded sprayer or hooded sprayer to emerged and 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. In addition, when Aim is used for weed suppression, additional sprayer cleanout is necessary to decrease chemical residue in tanks, spray lines, and nozzles.

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 and 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. Furthermore, 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 a herbicide labeled for Palmer amaranth suppression. Results from this study are 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**	**Year I**	**Year II**	**Year I**	**Year II**	**Year I**	**Year II**
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 Risk Assessment Tool

A weed risk assessment tool has been created by the Department of Crop and Soil Sciences at NC State University. The tool allows producers to enter field-specific tobacco weed management strategies and weed control efforts in previous crops to improve herbicide resistance management. The Risk Assessment file and instructions can be found on the left sidebar menu on the homepage of NC State Tobacco Portal (tobacco.ces.ncsu.edu).

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 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 *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 seeds 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%. 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 of flue curing 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 following 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 AND TANK CONTAMINATION

Residues from crop protection agents (CPAs), whether 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 (such as corn, cotton, or 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 *2025 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, air temperature and humidity restrictions, and application cutoff dates.
- Drift of any pesticide not labeled for tobacco production should be of great concern to every producer. However, drift of herbicides, specifically synthetic auxins, deserves special consideration due to tobacco's sensitivity to this class of products. Synthetic auxins are herbicides such as 2,4-D, aminopyralid, aminocyclopyrachlor, dicamba, picloram, and quinclorac. Some active ingredients (aminopyralid and picloram) have a long residual activity in the soil profile, while the soil activity of others (2,4-D and dicamba) are much shorter. These herbicides are used in a variety of vegetation control situations; therefore, soil carryover and foliar exposure must be considered when diagnosing a potential exposure event.

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 *2025 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 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 nozzle output is 10% 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:

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

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

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

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 739 milliliters per nozzle (3,785 ml = 1 gallon).

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

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

Enter the gpm result and mph to calculate gpa:

$$\text{gpa} = \frac{\text{gpm} \times 5{,}940}{\text{mph} \times \text{w}} \qquad \text{gpa} = \frac{0.195 \times 5{,}940}{3 \times 18}$$

gpa = 21.5

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

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

The 300 gallons will treat 14 acres (300 gallons / 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. After you obtain the number of gallons per treated acre, you must convert it to gallons per field acre using the following formula:

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

Example: You wish to apply Devrinol 50 DF at a rate of 4 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) 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).

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

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

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. However, this rate will cover more than one acre of tobacco because you are spraying only one-third of the land. To calculate the number of gallons per field acre, use the previously mentioned formula:

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

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

The sprayer is applying 8 gallons per acre of land. But for every 24 gallons of water added to the tank, you add 4 pounds of Devrinol 50 DF. Suppose you add 150 gallons of water to your tank. To calculate the acreage of tobacco this will cover:

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

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

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

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 3 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 *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. The output from the three nozzles should then be converted into gpm, and the result should be entered into the formula.

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% of each other.) Combine the output for all three nozzles for 1 minute. For this example, it totals 4,550 milliliters, or 154 ounces.

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

Enter that value into the formula:

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

If you want to apply a 4% contact solution, add 2 gallons of contact per 48 gallons of water. This will apply a 4% contact at 49.5 gallons of total solution per acre.

Some Useful Information for Calibrating a Sprayer

Value	Conversion
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 - burndown	Most annual grasses and broadleaf weeds that have emerged or cover crops	glyphosate, MOA 9 (numerous brands and formulations)	0.75 (lb a.e.)	Apply to emerged weeds 30 days or more before transplanting and before weeds are 6 inches tall. Tillage should occur no more than 15 days after application.
TOBACCO, FLUE-CURED Field, before transplanting - burndown	Most annual grasses and broadleaf weeds that have emerged or cover crops	paraquat, MOA 22 (Gramoxone SL 3.0)	1.6 to 2.5 pts	Apply to emerged weeds or cover crop measuring between 1 and 6 in. tall. Vegetation taller than 6 in. may not be controlled. Use a nonionic surfactant with ≥75% active agent at 0.25% v/v (2 pt/100 gal concentration) or a crop oil concentration with 15%–20% emulsifier at 1% v/v (1 gal/100 gal concentration). Apply at a minimum solution volume of 10 gal/acre (>15 GPA preferred). Use higher rates for dense weed or cover crop populations. Weeds that emerge after the application will not be controlled. **Applicators must complete the Paraquat Dichloride Training for Certified Applicators as required by EPA.** Visit https://www.epa.gov/pesticide-worker-safety/paraquat-dichloride-training-certified-applicators for more information.
TOBACCO, FLUE-CURED Field, before transplanting - burndown, some broadleaf weeds that have emerged	Most broadleaf weeds	flumioxazin, MOA 14 (Valor) EZ	1 to 2 fl. oz.	Apply to emerged weeds 30 or more days before transplanting. A minimum of one inch of rain or irrigation must also occur prior to transplanting.

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	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 are 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.
TOBACCO, FLUE-CURED Field, before transplanting	Most annual grasses and some broadleaf weeds	pendimethalin, MOA 3 (Prowl) 3.3 EC (Prowl) H2O (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 only once per season.
	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.

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	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.
TOBACCO, FLUE-CURED Field, after transplanting *(continued)*	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.
	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.

Table 6-4. *(continued)*

Crop	Weed	Herbicide, Mode of Action, and Formulation	Amount of Formulation Per Acre	Precautions and Remarks
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 are 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 in. 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 leaf body if suckers are controlled. When tobacco plants are not topped and are allowed to reach the full flower stage, yields are reduced by 20 to 25 pounds per acre per day (or about 1% 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:

- Usually allows topping to be completed before harvest begins, helping spread the workload away from the peak harvest period;
- Reduces the possibility of plants blowing over in a wind storm;
- Stimulates earlier root development, which increases fertilizer efficiency, drought tolerance, and alkaloid production; and
- 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 because 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 unnecessary 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, "Managing Nutrients," for more information on determining nitrogen rates.

Table 7-1. Sucker control with various rates of nitrogen at Kinston and Reidsville[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 6.2, 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 them. Contact alcohol chemicals desiccate (burn) tender sucker tissue, while 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+ and Drexalin Plus) is a contact-local systemic suckericide because it must touch the suckers to be effective, and it retards sucker growth by inhibiting cell division. However, contact-local systems are not translocated throughout the plant. 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, each of which is discussed below.

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 when 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 only be made 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% of the plants have visible buttons. The timing of chemical application is important because neither contacts nor flumetralin will adequately control suckers longer than an 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 10:00 a.m. and 6:00 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 lb per sq in. [psi]), and with a delivery volume of 50 gallons per acre. 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% solution. A 5% 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% solution. The mixtures should be strong enough to kill both tiny suckers in each leaf axil when the solution wets suckers less than an 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% for the C_8–C_{10} products or less than 3% for the C_{10} products, often control only one of the two or three sucker buds in each leaf axil. A good general rule is to apply a contact solution that chemically tops 5% to 10% 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+, 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 by hand 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, which prevent proper “rundown” of flumetralin into all the leaf axils.

Even though the flumetralin label allows for application of up to 1 gallon per acre, the general recommendation has been for application rates of 2 quarts per acre. Increasing flumetralin rates from 2 quarts per acre to 3 quarts or 1 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 2 quarts of flumetralin followed by one quart of flumetralin seven days later improves sucker control compared to 3 quarts of flumetralin applied in a single application.

This would indicate that increasing rates of flumetralin above 2 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. 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.

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 sweetpotatoes 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 expensive and not always available on the farm, depending on the scope of the farming operation or the degree of mechanization of other farming operations. Although 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, using 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: 2 or 3 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 + and 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 WHILE MINIMIZING MH RESIDUES

Since its introduction in the early 1950s, MH has saved many hours of labor. 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 initial use of MH 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 U.S. 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 U.S., domestic cigarette manufacturers and all members of the industry are very concerned about the poor public perception of any pesticide residues that could reduce tobacco use both here and abroad. Although domestic cigarette consumption is not increasing, the U.S. 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 in the near future.

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 2 gallons in 48 gallons of water; which makes a 4% solution. A 5% 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% 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% solutions were applied.

Weak contact solutions, those less than 4% for the C_8-C_{10} products or less than 3% for the C_{10} products, often control only one of the two sucker buds in each leaf axil. The suggested rates of the systemic chemicals therefore 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% 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. The 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% 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 10:00 a.m. and 6:00 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, but its control is further extended when preceded by one or two applications of alcohol contact.

Proper Use of Flumetralin (Prime+, 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. 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), although 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 sweetpotatoes, 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 2 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 5 to 6 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, rather than 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 is generally not suggested except on cool, cloudy days when the 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 for 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 [a.i.] per gallon of product; some products contain 2.25 pounds of a.i. 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 4 hours after the first application. Only a half-rate application (0.75 gallon of MH per acre) is needed if rain occurs between 4 and 10 hours after the first application. No reapplication is needed if rain occurs after 10 hours. 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. The 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

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 8 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 8 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 16 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, but this will ensure MH-free first primings.

After 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 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 MH off 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.

Consider Using an Alternative Sucker Control Program

The most effective sucker control programs include proper use of fatty alcohol contacts, flumetralin, and the labeled rate of MH. All 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% 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, 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 pounds a.i.). 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 pounds a.i.), but this 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 pounds a.i.). In this scenario, MH is applied with the second application of flumetralin and after the first harvest. Since Plucker Plus contains both flumetralin and a fatty alcohol, rate recommendations will differ compared to products containing only flumetralin.

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

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% 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 applying 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 on 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% 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% concentration for C_8-C_{10} products or a 3% 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 about 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% concentration for C_8-C_{10} alcohols (2.5 gallons in 47.5 gallons of water per acre) or a 3% 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 half a 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 of active MH per gallon) and 2 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 3 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 3 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% 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 of 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 2 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% 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 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 10 field tests, 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 additional trials, 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-nozzles-per-row arrangements was to concentrate relatively more of the total spray volume over the row centers as compared to the three-nozzle arrangements.

3 Nozzles/Row	**4 Nozzles/Row**	**5 Nozzles/Row**	
3—5—3	5—6•6—5	5	6
6—8—6	5—8•8—5	│	│
		3—8—3	3—6—3
		│	│
		5	6

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 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 relative sucker control 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

Treatment	TG Nozzle Sizes (per row)	Gauge Pressure (psi)	Application Speed[a] (mph)	Suckers per Acre[b] (number)	Suckers per Acre[b] (lb)
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 as good if not better sucker control as the more elaborate five-nozzle arrangements tested to date.

Whichever 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 gallons of spray volume per acre (gpa) can be calculated using the following formula:

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

Recently, there has been interest in the use of medium-to-high-output (25 to 50 gal/acre), ultracoarse (>650 μm) nozzles that would allow for the placement of one nozzle per row. The concept is that fine solution droplet sizes would be greatly reduced, thus eliminating the deposit of MH on the underside of leaves, and that a lower carrier volume might be used to reduce MH residue accumulation in middle and lower stalk positions. Field trials conducted in 2020 and 2021 tested these theories, and ultimately concluded that alternative nozzles could be used in flue-cured production without compromising sucker control or agronomic measurements (yield, quality, and value). However, cured leaf MH residues were not consistently reduced when alternative nozzles were utilized. More specifically, cured-leaf MH residues from alternative nozzles did not differ when measured in cutter, leaf, and tip stalk positions, nor when compared to the standard three-nozzle boom arrangement (Table 7-6).

The effect of carrier volume (25 vs. 50 gallons per acre) was also tested in these field trials. Within each stalk position group (cutter, leaf, and tip), cured-leaf MH residues were approximately 10 ppm higher when the carrier volume was lowered from 50 to 25 gallons per acre. It is possible that the lower carrier volume resulted in less solution runoff at the time of application, thus allowing for greater MH retention by plants. While our results do not support the use of alternative nozzles or carrier volumes, relative to the current recommendations, producers who have not had issues with MH residues in the past may consider these options. For example, a lower carrier volume will result in less water consumption and reduce the time required to treat with MH, and may therefore improve operating efficiency to a small degree. For additional information and guidance, please contact your local Extension agent.

Table 7-6. Maleic hydrazide (MH) residue response to nozzle type in cutter, leaf, and tip stalk positions [a]

	Cutter	Leaf	Tip
Nozzle type	**ppm**		
3-nozzle boom	159 a	109 a	102 ab
Single TG	154 a	112 a	109 a
TurboDrop XL	162 a	101 a	102 ab
Air Induction Turbo TwinJet	144 a	103 a	97 b
TurfJet	154 a	95 a	96 b

[a] MH application was 1.5 gallons/acre (2.25 lb MH/acre) which is greater than the current recommendation of 1 gallon/acre (1.5 lb MH/acre). The goal of this research was to maximize residue potential. Producers are encouraged to use reduced rates of MH.

USE OF ETHEPHON

Ethephon (Ethephon 2, Ethephon 2SL, Ethephon 6, or Super Boll) is the only chemical approved for yellowing tobacco in the field. Use of 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 if 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 with 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. Ethephon 6 and Super Boll contain 6 pounds of ethephon per gallon and are labeled to be used at 1 1/3 to 2 2/3 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 the curing gas ethylene 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 before 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 ethephon application in the field, rather than the addition of ethylene gas during yellowing, has the greatest positive impact on 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 3 in Table 7-6 documents no change in yellowing duration when treated leaves were classified as under-ripe. In addition, the longer that 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, in addition to label restrictions. Furthermore, research designed to compare yellowing time of leaves treated with ethephon 4 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. 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 all label directions for use, and obey all federal, state, and local pesticide laws and regulations.

Table 7-7. Effects of ethephon and ethylene gas on yellowing time (in hours) during the curing process

	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 7-8 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) (Oskie)	1.33 to 2.67 pt 2.67 to 5.33 pt	1 to 2 lb 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 tested, leaves begin to yellow in 24 to 72 hours, 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 hours 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!

Table 7-9. Chemical control of sucker growth

Type	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 a second application 3 to 5 days later at any time of the day, except if 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 longer than 1 inch. 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 longer than 1 inch. 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.
	Royal MH-30 SG	Normal sucker control	4 to 5 lb	

Table 7-9. *(continued)*

Type	Chemical and Formulation	Purpose	Amount of Formulation per Acre	Precautions and Remarks
CONTACT-LOCAL SYSTEMIC TYPE	Flumetralin (Prime+, Flupro, or Drexalin Plus) 1.2 lb/gal	Normal sucker control, power sprayer	2 qt	Mix chemical 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 inches within 24 hours before application and remove missed suckers. 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 hours 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 inch, 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 inch. 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.

NOTES

8. MANAGING DISEASES

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THE TOBACCO DISEASE SITUATION IN 2024

Tobacco diseases contributed to severe losses in 2024. An initial drought followed by a tropical storm caused significant damage, which was further worsened by diseases. County-level losses were estimated to range from 30% to 80%. The diseases of greatest concern were black shank, Granville wilt, and brown spot. The Plant Disease and Insect Clinic diagnosed over 150 independent samples. Of these, 13% of the samples were greenhouse diseases such as Pythium root rot, black root rot, bacterial soft rot, and Rhizoctonia damping off, and approximately 87% were field diseases such as black shank, Granville wilt, bacterial soft rot, and leaf spots. The weather was a significant factor for the development of these diseases, and management is increasingly difficult with limited chemical management options.

Greenhouse diseases are a continuing issue for producers. *Pythium* spp. and *Berkeleyomyces basicola* (black root rot) continue to cause the majority of greenhouse diseases throughout the state, and management strategies are limited. *Rhizoctonia solani* was observed in a few greenhouses. *Pythium* spp. and *R. solani* 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.

Early-season drought conditions, followed by heavy precipitation in July and an August tropic storm, led to a difficult growing season.

Leaf spots continue to damage tobacco in North Carolina. Due to the early drought, disease pressure for target spot was low. However, with the wet July (from a tropical storm and hurricane), incidences of brown spot and Erwinia leaf spot were high. Continuing to rotate available fungicide chemistries and maintaining good coverage during applications are important to limit the impact of target spot on production, though management strategies for other leaf spots are limited.

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.

DISEASE MANAGEMENT PRACTICES

An effective disease management program integrates a combination of cultural practices and chemical applications. Reliance on any one approach may risk failure to effectively manage diseases and the development of pathogen-resistant populations. Before planting, it is important to assess the factors contributing to disease development and plan disease management strategies to prevent and address disease development during the growing season. Factors to assess can include planting history, history of diseases and disease pressure in the field, and conducive environmental conditions.

Crop Rotation

Crop rotation is an effective and relatively inexpensive method of managing disease. Most economically significant diseases affecting tobacco are caused by pathogens that persist in the soil and can only reproduce in a limited range of hosts. In the absence of tobacco or other host plants, the soilborne pathogens start to die and the populations (propagules) are reduced. While crop rotation may not be feasible for all growers, it is beneficial to plan for crop rotations as a worthwhile investment towards disease management. Many North Carolina crops are good rotation crops that are effective at reducing the population of pathogens that cause disease in tobacco (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	Mod.[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. However, rotation with soybean or tomato will not aid in management of the guava root-knot nematode (*Meloidogyne enterolobii*).

[c] Rating is moderate if a root-knot resistant variety of sweetpotato is used. However, rotation with sweetpotato will not aid in management of the guava root-knot nematode (*Meloidogyne enterolobii*).

Length of rotation. When no rotation is conducted and tobacco is grown continuously, pathogen populations are allowed to build up and the risk of severe disease development increases. The longer the rotation, the greater the reduction of soilborne pathogen populations. A four-year rotation, in which three alternate crops are planted between tobacco, is more effective than a two- or three-year rotation. Similarly, a three-year rotation is more effective than a two-year rotation. Nevertheless, a two-year rotation, in which one alternate crop is planted between crops of tobacco, significantly reduces disease and is far more beneficial than continuous tobacco production.

Stalk and Root Destruction

Stalks and roots from the previous year's crop (crop debris) may also provide pathogens with host material that they can use to increase their populations. Therefore, the crop debris must be destroyed as soon after harvest as possible, regardless of whether diseases were observed or not (Table 8-2). Completing the listed tasks reduces populations of several tobacco diseases, including black shank, brown spot, Granville wilt, root-knot nematodes, tobacco mosaic virus, and tobacco vein banding mosaic virus, as well as certain insects, grasses, and weeds.

Furthermore, crop debris destruction exposes pests living in the debris to adverse environmental elements that can kill them or limit their growth. For example, root-knot nematodes (RKN) are very sensitive to drying, and when the root tissue surrounding RKNs decays, the RKNs are exposed to drying conditions. Additionally, tobacco mosaic virus (TMV) particles lose their ability to infect when they are outside of tobacco tissue. By destroying tobacco roots and stalks, TMV carryover may be reduced to a level at which less than 1% of tobacco plants become infected at transplanting. Removing TMV-infected tobacco plants before first cultivation may also prevent secondary spread.

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 two 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

For example, root-knot-resistant varieties are only resistant against the Southern root-knot nematode (*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 pathogen, but are quite susceptible to race 1. See the section on black shank for a more complete discussion of resistance to that disease. Table 8-3 also provides information about varieties resistant to Granville wilt, root-knot nematodes, and tobacco mosaic virus (TMV).

Table 8-3. Resistance of flue-cured tobacco varieties to black shank, Granville wilt, root-knot nematode, and tobacco mosaic virus from 2016–2024 in the Official Variety Testing Program

	Black Shank					Granville Wilt				
Variety	**Ph[a] gene**	**Wz[b] gene**	**Susceptibility scale values[c]**	**Designation[d]**	**Survival (%)[e]**	**Susceptibility scale values[c]**	**Designation[d]**	**Survival (%)[e]**	**RKN[f]**	**TMV[g]**
CC143	-	-	2.4	Resistant	76	2.3	Resistant	69	R	R
CC145	-	-	1	Highly resistant	89	1.8	Resistant	77	S	S
CC603	+	-	1.3	Highly resistant	79	2.1	Resistant	78		
CC607	+	-	4.7	Moderately susceptible	18	2.9	Moderately resistant	78		
CC700	+	-	2.8	Moderately resistant	72	3.0	Moderately resistant	68	R	S
CC1063	-	-	1.7	Resistant	84	2.7	Moderately resistant	73	R	S
GF318	+	-	5.1	Moderately susceptible	52	3.1	Moderately resistant	69	R	R
GL26H	-	-	6.9	Susceptible	41	5.3	Moderately susceptible	46	R	R
GL365	-	-	1.6	Resistant	86	3.0	Moderately resistant	65	R	S
GL386	-	-	6.2	Moderately susceptible	15	4.8	Moderately susceptible	49		
GL395	-	-	2.3	Resistant	75	3.7	Moderately resistant	67	R	S
K326	-	-	7.4	Susceptible	43	5.7	Moderately susceptible	41	R	S
K346	-	-	1.8	Resistant	80	2.1	Resistant	77	R	S
NC 196	+	-	1.7	Resistant	82	3.4	Moderately Resistant	66	R	S
NC 299	+	-	6.8	Susceptible	42	1.9	Resistant	75	R	S
NC 606	-	-	3.3	Moderately resistant	66	3.1	ModeratelyResistant	62	R	S
NC960	+	+	1.2	Highly resistant	75	3.6	Moderately resistant	65		
NC991			1.4	Highly resistant	84	2.9	Moderately resistant	75		
NC993			4.1	Moderately resistant	34	2.3	Resistant	73		
NC 996			1.5	Highly resistant	87	1.2	Highly resistant	79		
NC1006			3.2	Moderately resistant	66	4.1	Moderately resistant	55		

	Black Shank					Granville Wilt				
Variety	Ph[a] gene	Wz[b] gene	Susceptibility scale values[c]	Designation[d]	Survival (%)[e]	Susceptibility scale values[c]	Designation[d]	Survival (%)[e]	RKN[f]	TMV[g]
NC1007			5	Moderately susceptible	27	3.6	Moderately resistant	67		
NC 1226	+	+	2.7	Moderately resistant	67	1.5	HighlyResistant	82	R	S
PVH1920			4.7	Moderately susceptible	17	3.1	Moderately resistant	64	R	S
PVH1940	+	-	2.9	Moderately resistant	55	3.0	Moderately resistant	73		
PVH1980			5.3	Moderately susceptible	20	2.5	Moderately resistant	76		
PVH2233			8.7	Highly susceptible	3	2.9	Moderately resistant	70		
PVH2254	-	-	9	Highly susceptible	3	3.1	Moderately resistant	78	R	R
PVH2310	+	-	8.9	Highly susceptible	1	3.7	Moderately resistant	50	R	R
PVH2343	-	-	7.4	Susceptible	6	2.2	Resistant	76	R	R
PXH53			3.6	Moderately resistant	66	2.0	Resistant	82		

[a]The Ph gene from Tex-Mex tobacco (Nicotiana plumbaginifolia) has been incorporated into many flue-cured tobacco cultivars to provide resistance against races 0 and 3 of P. nicotianae

[b]The Wz gene confers resistance to race 0 and race 1.

[c]Susceptibility scale 1–9 is based on the area under the disease progress curve (AUDPC), calculated from multiple disease incidence assessments throughout the season, ranging from lowest disease development (1) to highest (9). Black shank is based on evaluations from 2023–2024, and bacterial wilt is based on evaluations from 2022–2024.

[d]Designations are based on the susceptibility scale, ranging from highly resistant (<1.5), resistant (1.5–2.5), moderately resistant (2.6–4.5), moderately susceptible (4.6–7.5), susceptible (7.6–8.5), and highly susceptible (8.5–9).

[e]Survival ratings are the percent survival rates based on the observed percent of healthy plants across three years of data collection in fields heavily infested with disease. High ratings represent a higher level of resistance.

[f]Varieties with resistance to race 1 and 3 of the Southern root-knot nematodes = R; susceptible varieties = S, based on evaluations from 2016–2019. No commercial tobacco varieties have resistance to the guava root-knot nematode (Meloidogyne enterolobii).

[g]Varieties with resistance to tobacco mosaic virus = R, susceptible varieties = S, based on evaluations from 2016–2019.

Fumigants, Fungicides, and Nematicides

Fumigants, fungicides, and nematicides are all pesticides that growers can integrate into their disease management approach. All pesticides suppress or control disease through different modes of action (the way they control disease). Fumigants are pesticides that volatilize into a gas when applied to soil, and offer broad-spectrum suppression of Granville wilt and nematodes. Narrow-spectrum pesticides suppress and control more targeted diseases, such as black shank and nematodes. Protectant foliar fungicides offer protection from foliar diseases, such as target spot and Ridomil-insensitive blue mold. To ensure the long-term efficacy of pesticides and prevent the development of pesticide-resistant pathogen populations, it is important to rotate applications of pesticides with different modes of action, when possible.

All pesticides are preventative rather than curative, and are more effective when applied before the disease develops. It is important to identify the causal agent of a predicted or observed disease before chemical controls are used, as pesticides are labeled and tested for efficacy against specific pathogens. Efficacy of chemical controls are affected by disease pressure, climatic conditions, and the use of other management strategies. For example, soil applications are more effective when proper soil preparation creates good tilth and when temperatures are favorable for reducing volatility of the product and chemical injury.

Additional Helpful Cultural Practices

The following practices promote healthy tobacco plant growth and reduce environmental conditions conducive to disease. This allows tobacco the best chance at resisting or overcoming disease while reducing the population of pathogens.

Formation of a high, wide bed (row). Preparing high, wide beds in the field creates conditions for proper tobacco root development. High, wide beds allow for the conservation of soil moisture during dry periods and water drainage for root systems, which may otherwise become waterlogged and diseased during wet periods. While foliar diseases are more likely to develop in drought-stressed tobacco plants, root and vascular diseases are more likely to occur when roots are compromised and lack proper oxygenation.

Spacing. Tobacco plants that are spaced too closely often develop more disease than those planted farther apart in the row. Spacing specifically influences foliar diseases, such as brown spot, target spot, and blue mold, in which increased leaf moisture leads to more leaf spots. Wider spacing provides better drying conditions for the lower leaves by increasing sunlight and air flow throughout the canopy. Additionally, fungal foliar pathogens are often stressed by light exposure and slow in growth.

Balanced fertilization. Tobacco diseases are generally more severe in nutrient-stressed plants. Balanced fertilization allows for healthy tobacco plants that may resist or overcome disease. Root-knot nematodes and black shank are more severe in tobacco fields that are deficient in potassium. Black shank may also be more severe in tobacco fields with excess nitrogen.

Order of cultivation when disease is present. When disease occurs in patches or isolated fields, harvest the plants in the affected patches or fields last to reduce the chance of spreading the pathogens to non-diseased areas. After cultivation, sanitize equipment with a 10% bleach or other detergent solution and rinse with water using a power washer. If unable to use detergent or a power washer, a water rinse with a hose to remove soil and debris is better than no rinse at all.

MANAGING THE MAJOR DISEASES

Transplant Diseases

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

Diseases in greenhouses. The most common greenhouse diseases are caused by *Rhizoctonia solani* (damping off), *Sclerotinia sclerotiorum* (collar rot), *Pythium* spp. (damping off), *Berkeleyomyces basicola* (black root rot), *Pectobacterium carotovorum* (bacterial soft rot). *Rhizoctonia* generally causes damping off before clipping begins, and *Sclerotinia* causes damping off after clipping. *Pythium* damping off and black root knot occur at any time and are preceded by extensive yellowing of the plants. Tobacco mosaic virus (TMV) is rare under good sanitation practices but it is devastating where it occurs.

Sanitation practices. Sanitize and rinse the blades and underside of the deck with 50% bleach solution before clipping of each greenhouse. Ensure that all clipping debris is removed (vacuumed by mower). Avoid clipping too much of the plants in one pass or allowing mower bags to become too full, as this causes more clipping debris to fall back into the trays. Clipping debris in the trays or on the plants increases humidity in the plant leaves and promotes the development of collar rot and bacterial soft rot.

Before reusing, thoroughly wash and dry used trays. Dipping trays is not an effective way to kill pathogens. Steaming trays at 176°F for 30 minutes is an effective alternative to fumigation. Steaming trays at temperatures slightly below 176°F (no less than 158°F) for 2 hours can give similar disease control results as steaming at 176°F for 30 minutes. Tray steaming will not kill the black root rot pathogen or TMV. Growers who know that greenhouse transplants were a source of TMV or black root rot should dispose of the trays that contained the infected transplants and purchase new ones.

Environmental conditions. Greenhouses should be fully ventilated when temperatures are not cold enough that it would 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 development. *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. To kill pathogens when greenhouses are not in use, close the greenhouses in July or August to allow temperatures to reach 140°F eight hours per day for seven days. Heat-sensitive items should be removed prior to closing the greenhouses, and adequate moisture should be maintained in the house.

Other precautions: Never dump plants or used media within 100 yards of a greenhouse. After 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% bleach solution. Use special care in preventing field soil from contaminating water beds in float systems. Do not recycle pond water among beds because it can be a source of inoculum for disease. 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. Tobacco-product users should avoid entering the greenhouse or sanitize hands for at least one minute with a 20% dry milk solution. Do not allow weeds, especially horsenettle, to grow in the greenhouse.

To ensure that blue mold does not overwinter, tobacco should not be grown for any reason during a three-month period between October and February. Should blue mold be a concern, a preventative spray of Dithane Rainshield or other mancozeb products may be applied weekly after plants reach the size of a quarter.

Field Diseases

The following sections present general information about some of the most common or recently discovered diseases. Diseases are listed in alphabetical order.

Black shank. Black shank is caused by a soil-inhabiting, fungal-like organism named *Phytophthora nicotianae*, which belongs to a group of the most destructive plant pathogens, oomycetes. Oomycetes, also known as water molds, thrive in high-moisture climates. The black shank pathogen produces three types of spores, including survival structures (chlamydospores) that can survive in soil from four to six years. The pathogen spreads whenever infested soil is moved on machinery and other equipment, irrigating fields with infested surface water, by water washing soil from one part of the field to another, by moving transplants with infested soil around the roots, or any other means by which infested soil is moved. When conditions are conducive for disease, the pathogen produces motile, swimming spores (zoospores) that infect tobacco roots and sometimes infect stalk stems at leaf scars (where leaves fall off). Irrigation and rain can splash spores onto leaves, and cause leaf infections that develop as brown, circular spots.

The symptoms of black shank are yellowing and wilting of leaves. After infection, 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. The presence of discs is not solely diagnostic of black shank and can occur due to other factors, such as drought or lightning. Likewise, not all plants with black shank exhibit this symptom. Rotation, varietal resistance, and chemicals should be integrated into a management program to reduce damages caused by black shank (Figure 8-1).

There are different sources of resistance used in available varieties. Many flue-cured tobacco varieties contain multiple genes that may confer polygenic resistance, to races 0 and 1 of the black shank pathogen. Polygenic resistance has been the predominant form of resistance for many years; however, new varieties bred with monogenetic (one gene) resistance, such as with the *Ph* or *Wz* gene, have insufficient polygenic resistance.

A long-term reliance on monogenetic resistance can lead to shifts in the pathogen's race populations and eventual breakdown in resistance. The *Ph* gene, for example, is a single gene that confers resistance to races 0 and 3 of the pathogen. However, when varieties with the *Ph* gene are continuously planted, race 1 becomes more prevalent, even if it was not initially the predominant race. Similarly, the *Wz* gene confers resistance to races 0 and 1, but continuous use of *Wz* varieties allows *Phytophthora nicotianae* populations to overcome resistance. To prevent the development of resistant pathogen populations, it is crucial to rotate resistance traits and incorporate fungicides in management strategies.

Timing is crucial in an effective chemical-control program for black shank. Fungicides must be applied within the first seven to 10 days after transplant to be most effective. After this period, plants may be infected but not yet exhibit symptoms, and fungicides will not provide effective control. Fungicides are only systemic upwards through the plant, and the primary target for black shank control is at the roots; thus, fungicides applied to the soil surface should be incorporated near the root system by cultivation.

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-like pathogen (Peronospora tabacina) in the same group of pathogens as black shank. The blue mold pathogen spreads from infected seedlings. In 1979 and 1980, blue mold caused widespread losses in plant beds and fields throughout North Carolina. Its occurrence was sporadic until 1995, when it became widespread again. It has since become less common and sporadic in the last decade.

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 multiply rapidly 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

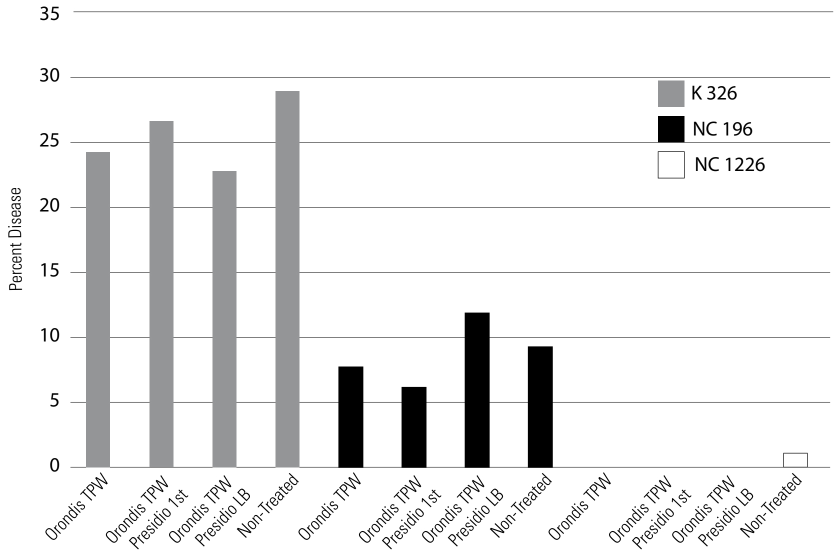

Figure 8-1. Flue-cured tobacco varieties (K 326, NC 196, NC 1226) with varying levels of resistance to black shank in combination with three different fungicide programs containing Orondis Gold (oxathiapiprolin + mefenoxam) and Presidio (fluopicolide) at the black shank nursery during the 2019 growing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

plant and interferes with normal plant growth, which results in stunting, distortion, and the eventual death of the plant. Both foliar and systemic infections cause severe losses under favorable environmental conditions.

Because the spores of the blue mold pathogen spread through the air, crop rotation and stalk and root destruction do not affect this disease in North Carolina. The pathogen does not overwinter in North Carolina, so predicting future infestations and any 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. For Ridomil-insensitive blue mold, dimethomorph (Forum) or acibenzolar-S-methyl (Actigard) are required for control. Forum may only be applied 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.). The brown spots caused by the disease are often irregularly shaped, have concentric rings, and expand up to 1 inch in size. Spores may also be observed within the rings of the spots. Brown spot may be considered an "opportunistic" pathogen because it causes disease on older or damaged leaves. It is often not an issue for tolerant varieties managed with good cultural practices, such as proper planting density and canopy management. However, it may be destructive during periods of extended rainfall late in the harvest season or on prematurely senescent or damaged plants.

Fusarium wilt. Fusarium wilt is a significant concern for growers in certain areas of the state. It is caused by a soilborne fungus (*Fusarium* spp.) that can persist in a field for decades due to decaying organic matter in the soil or survival spores (chlamydospores) that are resistant to adverse conditions. Fusarium wilt may also be considered an "opportunistic" disease, as it is destructive in stressed tobacco plants with root wounding or nematode infections. Although crop rotation and stalk and root destruction provide some benefit, these practices do not significantly reduce Fusarium wilt development because of the fungus' ability to live on organic matter and form strong, resting spores.

Granville wilt. Granville wilt is caused by a bacterium (*Ralstonia solanacearum*) that inhabits the soil. Similar to black shank, the bacterium spreads whenever infested soil is moved. Infection occurs when bacteria enter wounds or natural openings in the root system. Cultivation and nematode damage can increase the incidence of this disease, so minimizing root damage and controlling nematodes will help with disease control.

Granville wilt appears first as a wilting on one side of the plant. As the disease progresses, the entire plant wilts and 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 dark streaks that extend up the stalk just beneath the outer bark. Another diagnostic characteristic may be bacterial streaming, which can be observed as streams of bacteria oozing from the end of a cut stalk when the stalk is placed in a glass of room-temperature water.

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. Infected plants may also not show obvious systems until after heavy rain, in which the plants become water stressed.

Management of Granville wilt should integrate the use of resistant varieties (Table 8-3), fall or spring fumigation (Table 8-4), and cultural practices. Granville wilt bacteria also can infect tomatoes, white potatoes, peppers, eggplants, and peanuts. Good crop rotations can include fescue, small grains, or soybeans. Weeds such as ragweed can also be infected by the bacteria and should be controlled. Destroy stalks and roots immediately after harvest.

Hollow stalk (soft rot). Hollow stalk (caused by *Pectobacterium* 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. The use of some contact sucker-control agents may also lead to an increase in hollow stalk, especially if the leaf axil tissue is damaged. Soon after infection, a rapid browning of the pith occurs, followed by general soft rot and collapse of the tissue. Top leaves often wilt, and the infection spreads downward; the leaves droop or fall off, leaving the stalk bare. Diseased areas may show black bands or stripes that can girdle the stalk. In another phase of the disease, a soft decay appears at the junction where leaf petioles are attached to the stalk.

Table 8-4. Granville wilt management

Cultural

Rotate with fescue, small grains, or soybeans. Control weeds.

Use varieties with high levels of resistance (see section on variety selection).

Destroy stalks and roots immediately after harvest.

Avoid root wounding.

Manage nematodes.

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

* Allow three weeks from application to transplanting.

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

In times of severe rainfall, water splashing can lead to large, water-soaked lesions that turn brown, ringed, and with a tinge of green.

The bacterial pathogen is usually present in soil, on plant surfaces, or on worker's hands. The bacterium does not cause significant disease unless there is frequent rainfall and high humidity, which together favor infection and subsequent disease development.

If infected leaves are harvested and cured, the leaves will often develop barn rot. To prevent barn rot from developing, harvest leaves when dry and ensure proper ventilation. When leaves are harvested wet, running a fan while loading and during the first 24 hours at room temperature before the yellowing phase will help remove moisture from the leaves and barn.

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. ultimum* var. *ultimum* and *P. myriotylum*. Some *Pythium* species can be carried onto fields by 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 infect a large number of host plants, including peppers, tomatoes, corn, cucumbers, and peanuts, among others.

Pythium can affect tobacco at any growth stage in the field. Infected seedlings will experience damping-off, root and stem rot, and feeder root necrosis, while plants will exhibit Pythium stem rot. Similar to black shank, Pythium stem rot will cause wilting and yellowing. In most cases, Pythium stem rot affects some roots at the soil line level and most of the lower stem, causing sunken black lesions that will continue to grow upward in the stem.

High temperatures and soil moisture favor the development of Pythium stem rot. The incidence of *Pythium* is sporadic and no resistant varieties have been identified for the disease. *Pythium* can be managed with chemical controls and cultural practices recommended for black shank control.

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 management is to keep populations at non-destructive levels. Although a single nematode is not harmful, high populations have a devastating effect. Under favorable conditions, root-knot nematodes can complete their life cycle 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 Southern root-knot nematode, *Meloidogyne incognita*. However, other *Meloidogyne* species are increasing their presence in this state, especially *M. arenaria*, *M. javanica*, and *M. hapla*, which can cause severe damage. The spread of *M. javanica* and *M. hapla* is a threat to tobacco 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 (races 2 and 4) appear to be spreading in the state. More recently, *M. enterolobii* has been introduced into North Carolina, and has been confirmed in 16 counties, mainly in the central coastal plains. This nematode species is particularly aggressive and is difficult to manage. If *M. enterolobii* is suspected in a field, contact your local N.C. Cooperative Extension agent, and submit a sample for molecular identification to the NCDA&CS Nematode Assay Laboratory.

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 index below. Galls will appear as bumps or “knots” along a normally smooth root.

- Low infestation: 0%–10% of root area covered with galls
- Moderate infestation: 11%–25% of root area covered with galls
- High infestation: 26%–50% of root area covered with galls
- Very high infestation: 51%–100% 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 from several locations in each field. 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 NCDA&CS Nematode Assay Laboratory. The samples should ideally be taken in the fall (before December 1) to provide information and guide nematode management decisions for the following cropping cycle. However, a soil sample for nematode analysis can be collected at any time of the year, so long as the soil is in good condition (not too wet, not too dry, and not frozen). No more than 5 acres should be represented by one sample, which should consist of at least 20 cores or subsamples from 6 to 8 inches deep. Gently but thoroughly mix the collected soil cores in a clean bucket, and place a 500-cc portion (approximately 1 pint) into a plastic bag. Place the bag into a Nematode Assay Lab submission box and label the box with an identifying code that will help you remember where the sample was collected. Samples must not be allowed to dry or be heated above 80°F. Do not freeze the soil samples. Nematode counts obtained from samples taken in the spring prior to planting are usually lower than those taken in the fall. Numbers reported to you and your local Extension agent represent the number of nematodes per pint of soil. Additional information about soil sampling for nematode analysis is available from the NCDA&CS. For predictive sampling instructions, see www.ncagr.gov/divisions/agronomic-services/nematode-assay/standard-testing/predictive/collect-samples. For diagnostic sampling instructions, see www.ncagr.gov/divisions/agronomic-services/nematode-assay/standard-testing/diagnostic/collect-samples.

As with other tobacco diseases, management 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.

Target spot. Target spot (*Rhizoctonia* spp.) has been prevalent in North Carolina since 1984. The disease has caused significant losses in North Carolina throughout the years, averaging losses of $7 million annually. The soilborne fungus persists in the soil through survival structures (sclerotia), which produce hyphae or spores (basidiospores) in warm, humid-to-wet environments. The spores will spread through the air or rain splashing.

Similar to brown spot, target spots are brown and have concentric rings, but tend to have smoother margins. The centers of the spots rapidly become very thin and shatter when slight pressure is applied, leaving cracked spots or holes. Spots are first observed in the lower leaves but may spread to leaves at any height on the plant. Removing the lower leaves will reduce the population of the fungus when the leaves are infected, and will reduce humidity by increasing airflow throughout the canopy.

Tobacco plants should be adequately fertilized, as nitrogen-deficient plants are more susceptible to disease. The target spot pathogen has a broad host range, though wheat and corn are poor hosts of the fungus. However, removing leaves and stalks after harvest will help reduce the growth of the fungus. In 2006, Quadris (azoxystrobin) was registered for control of target spot. Quadris is a locally systemic product, which can only relocate a short distance from the point of application. Therefore, drop nozzles are strongly recommended for Quadris application in the field to ensure uniform coverage of the foliage. To minimize the risk of fungicide resistance,

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

Material[a]	Rate/Acre	Method of Application	Waiting Period	Efficacy Rating[b]
Chloropicrin 100c (chloropicrin)	3 gal	Fumigant—row[d]	21 days	Poor
Chlor-O-Pic 100c (chloropicrin)	3 gal	Fumigant—row	21 days	Poor
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%)	3.5–7 pints/acre	Pre-plant broadcast or band treatment and incorporate	7 days	Fair
Velum Prime (fluopyram)	6.5–6.8 fl oz/acre	Transplant water application	N/A	Good
Vydate C-LV (oxamyl)	68 fl oz/acre	Pre-plant broadcast or band treatment and incorporate	1 day	Good

[a] Most nematicides can damage plants under certain conditions. Greenhouse-grown plants may be more sensitive to this type of injury. Read and follow all label directions.

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

[c] The fumigant product chloropicrin offers effective control of other soilborne diseases. However, when applied alone, it offers little-to-no nematode control.

[d] 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.

Quadris should be used with fungicides in concert with other modes of action, such as Manzate Pro-stick (24C label for use in North Carolina tobacco).

Tobacco mosaic virus. Tobacco mosaic virus (TMV) is one of the most contagious tobacco diseases that growers encounter in North Carolina. The virus is spread in the sap of diseased plants. Anything that moves sap or fluids from a diseased plant to a healthy plant will relocate the virus, including machinery used during cultivation and the hands or clothing of workers. It does not spread through air currents or insects. After a TMV particle enters the plant, it becomes a part of that plant and will persist in the plant tissue. Disease is most severe on drought-stressed plants.

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

Control of TMV may include a combination of resistant varieties (Table 8-3) and prevention. Field rotations, clean equipment, and discarding of seedling trays (if TMV incidence was at least 20% by layby in any field) are 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% bleach solution. Tobacco-product users should avoid handling crops. No chemicals are labeled for mosaic control, although the milk-dip treatment is beneficial as workers perform tasks within the crop.

Tomato spotted wilt virus (TSWV). TSWV is a potentially devastating disease of tobacco in North Carolina that is often a major concern in southern counties. First detected in North Carolina in 1989, this disease has been observed sporadically throughout the years, and was widely found in the 2022 and 2023 growing seasons.

TSWV has a broad host range including tomatoes, peppers, peanuts, white potatoes, and weeds and ornamentals. Winter weeds, such as annual smallflower buttercup, mouse ear chickweed, common chickweed, spiny sowthistle, perennials dandelion, and Rugel's plantain are often the major source of infection. As the winter annuals begin to die in the spring, adult thrips are forced to move to alternative plants, including tobacco. TSWV is moved from plant to plant by thrips that fed on infected plants during their larval stage.

In most years, the tobacco thrips are the most important vector of TSWV early in the field season. However, the western flower thrips were abundant early in the 2002 season. Mild winter conditions allow for increased thrips populations and increased viral inoculum in winter weeds, which leads to increased TSWV incidence in the following tobacco crops.

Symptoms of TSWV vary with plant age, virus strain, and environmental conditions. Newly transplanted seedlings die and decay rapidly. As such, seedling infections are often misdiagnosed as other seedling diseases or transplanting problems. Infected tobacco plants will display characteristic foliar symptoms. On young plants, dark reddish-brown specks and leaf distortion are common on the youngest leaves. Older plants will have reddish-brown necrotic spots or ring spots, 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 caused by the virus. 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, which often resemble burns from contact sucker chemicals. Streaks also occur within the pith. Plants that are infected around flowering are less likely to be significantly affected, as symptoms on these plants are generally localized and 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 distributed randomly throughout a field, whereas TSV is usually concentrated near a particular field border. The only way to be sure which viruses are present is to use a reliable assay procedure to identify the virus. Assays may be conducted by submitting plant samples to the NCSU Plant Disease and Insect Clinic.

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. This spreads the disease among weed hosts, increases thrips survival, and increases their populations. Colder winters may suppress thrips populations and the spread of the disease among weeds, which results in a smaller inoculum source in the spring.
- An early, dry spring causes winter hosts to turn 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 during transplanting. As the crop ages, it is progressively less likely to be infected by 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. Over-the-top 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, although 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.

Most economically important TSWV infections occur within a few days to two weeks after transplanting. Thus, protection should be in place before transplanting. Application of any chemicals after the virus has infected the plant will be of little benefit, if any.

The application of Actigard, alone or in combination with Admire or Platinum, to seedlings in the greenhouse may be an effective and economical management tactic. Early leaf damage and stunting may be possible when Actigard and high rates of Admire are used, so combined uses should be limited to fields with a history of TSWV losses higher than 10%. Where TSWV losses have been less r than 10%, Admire alone is recommended at 0.8 to 1.2 ounces per thousand plants (Admire 2F at 1.8 ounces/thousand plants) in the greenhouse. Lower rates of Admire are adequate if only insect control is 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.

As rates may change, read the label to determine the appropriate rate before treating plants. Injury is most likely to occur when plants are stressed. If Actigard is used, ensure 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 choosing application in the float bed water, use Table 8-7 to calculate the required quantity.

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.
For example: 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 rather an injury caused by ozone, the common air pollutant. Ozone is heavy oxygen (O_3) and is produced by internal combustion engines and 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. Weather flecking 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. Some varieties are much less sensitive to weather fleck than others. 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 affect tobacco. Growers may be able to design a disease management plan for their main diseases of concern by keeping a record of the disease that occurs in their fields. Designing a "tobacco disease map" of each field will also help growers see what areas of their field are more prone to certain diseases. 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 the level of infestation. For black shank and Granville wilt, the average percentage of plants diseased within a field is a good indication of the level of that disease in the field.

OTHER REFERENCES

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

Compendium of Tobacco Diseases is available from the American Phytopathological Society (APS). Find more information at my.apsnet.org/ItemDetail?iProductCode=41175.

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

North Carolina Department of Agriculture and Consumer Services
Agronomic Division, Nematode Assay Section
4300 Reedy Creek Road
Raleigh, NC 27607-6465

A PRECAUTIONARY STATEMENT ON PESTICIDES

Pesticides must be used carefully to protect against human injury and harm to the environment. Accurately diagnose pest problems and select the proper pesticide, if one is needed. When possible, use different modes of action when repeated applications of pesticides are necessary for controlling disease. 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 local N.C. Cooperative Extension center)

Disease	Cultural Management	Chemicals (read and follow the label)	Comments
Anthracnose *(Collectotricum gloeosporioides)*	Clip beds frequently to allow foliage to dry.	Manzate Pro-stick (mancozeb) Greenhouse 0.5 lb/100 gal (sprayed) Howler (Pseudomonas chlororaphis strain AFS009) 2.5-7.5 lbs/100 gal Theia (Bacillus subtilis strain AFS032321) 1.5-5 lbs/100 gal	Spray foliage to runoff, and maintain thorough coverage with fungicide when weather is cool and damp. Fungicide may be sprayed every 5 to 7 days.
Blue mold *(Peronospora tabacina)*	Clip beds frequently to allow foliage to dry.	Manzate Pro-stick (mancozeb) Greenhouse 0.5 lb/100 gal (sprayed) Aliette WDG 0.5lb/50 gal water Howler (Pseudomonas chlororaphis strain AFS009) 2.5-7.5 lbs/100 gal Theia (Bacillus subtilis strain AFS032321) 1.5-5 lbs/100 gal	Spray Manzate Pro-stick weekly from the time plants are the size of a quarter. Apply preemptively or at the first sign of blue mold. Do not exceed two applications.
Collar rot *(Sclerotinia sclerotiorum)*	Do not 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.	Howler (Pseudomonas chlororaphis strain AFS009) 2.5-7.5 lbs/100 gal Theia (Bacillus subtilis strain AFS032321) 1.5-5 lbs/100 galNone	Efficacy of biologicals has not been assessed.

Disease	Cultural Management	Chemicals (read and follow the label)	Comments
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) 4E 1.4 fl oz/100 gal float water See black shank. Howler (Pseudomonas chlororaphis strain AFS009) 2.5-7.5 lbs/100 gal Theia (Bacillus subtilis strain AFS032321) 1.5-5 lbs/100 gal	Thoroughly mix into float water 2 to 3 weeks after seeding.
Soilborne diseases (Root-knot nematode, Granville wilt, black shank, some damping-off)	Plant bed: Select warm, well- drained site. Greenhouse trays: Wash trays. Steam at 160°F to 175°F for 30 min.	Nematodes: Telone II 6 gal/acre Disease: Chloropicrin 3 gal/acre Pic + 4 gal/acre	Thoroughly prepare bed. Fumigate when 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.	Manzate Pro-stick (mancozeb) Greenhouse 0.5 lb/100 gal (sprayed) Quadris 0.14 ml/100 sq ft Howler (Pseudomonas chlororaphis strain AFS009) 2.5-7.5 lbs/100 gal Theia (Bacillus subtilis strain AFS032321) 1.5-5 lbs/100 gal	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 the 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% household bleach or steam clean mower. Spray plants within 24 hours of transplanting.
Angular leafspot (*Pseudomonas syringae*)	If disease is severe, avoid working in fields when foliage is wet.	Theia (Bacillus subtilis strain AFS032321) 1.5-5 lbs/100 gal	Control is not usually necessary.
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 a 21-day waiting period between application and transplanting.

Table. 8-9. Condensed management guide for field diseases (for more information, contact your local 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 beds. 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	In fields with histories of black shank, use all cultural practices. Use Ridomil just before transplanting. Apply again at first cultivation and layby if risk of disease is high. Ultra Flourish 2E brand of mefenoxam used at 2x 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 8-3.
		Presidio at 4 fl oz/acre	Soil-directed spray.
		Orondis Gold (see label for rates)	Greatest level of control when used in transplant water.
		Howler (Pseudomonas chlororaphis strain AFS009) 2.5-7.5 lbs/acre	Biological controls may be applied every 7 to 14 days, as needed. Efficacy of biologicals has not been assessed.
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	Spray at first threat of blue mold and every 7 to 10 days. See label for spray volumes.
		Actigard 50W at 0.5 oz/a in 20 gal water	Apply after plants are 18 inches tall. Repeat in 10 days. See label for precautions.
		Manzate Pro-stick (mancozeb) at 1.5 to 2 lb/100 gal	Spray foliage weekly for complete coverage. Stop spraying all products 21 days before harvest.
		Aliette WDP at 2.5 to 4 lb/acre	Apply preemptively or at first sign of blue mold. Apply until 3 days before harvest.
		Quadris at 6 to 12 fl oz/acre	See label for spray volumes.
		Revus at 8 fl oz/acre	Do not apply within 7 days before harvest.
		Presidio at 4 fl oz/acre	See label for spray volumes.

Table 8-9. *(continued)*

Disease	Cultural Management	Chemicals (read and follow the label)	Comments
Blue mold (*Peronospora tabacina*) (continued)		Forum at 2 to 8 oz	Increase rate and spray volume as crop size increases. MUST be used in a tank mix with another fungicide (non-Group 40) active against blue mold.
		Copper Octanoate (Cueva) 50.8 gal/acre	Use on tobacco in transplant beds (or on field grown plants). Do not reapply within 10 days.
		Howler (Pseudomonas chlororaphis strain AFS009) 2.5-7.5 lbs/acre Theia (Bacillus subtilis strain AFS032321) 1.5-5 lbs/acre	Biological controls may be applied every 7 to 14 days, as needed. Efficacy of biologicals has not been assessed.
Brown spot (*Alternaria alternata*)	Avoid close plant spacing. Control suckers. Avoid excess nitrogen. Control nematodes. Use tolerant varieties.	Howler (Pseudomonas chlororaphis strain AFS009) 2.5-7.5 lbs/acre Theia (Bacillus subtilis strain AFS032321) 1.5-5 lbs/acre	Harvest as often as necessary to save tobacco. Biological controls may be applied every 7 to 14 days, as needed. Efficacy of biologicals has not been assessed.
Etch Tobacco Etch Virus	None	None	No control available.
Frogeye leaf spot (*Cercospora nicotianae*)	None	Theia (Bacillus subtilis strain AFS032321) 1.5-5 lbs/acre	Chemical controls are not usually needed.
Fusarium wilt (*Fusarium oxysporum f.* sp. *nicotianae*)	Rotate. Destroy stalks and roots. Avoid root wounding. Use resistant varieties. Control nematodes.	Telone II 6 gal/acre Howler (Pseudomonas chlororaphis strain AFS009) 2.5-7.5 lbs/acre Theia (Bacillus subtilis strain AFS032321) 1.5-5 lbs/acre	Significant problem only when root-knot or root injury is present. Biological controls may be applied every 7 to 14 days, as needed. Efficacy of biologicals has not been assessed.
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.	None	None

Table 8-9. *(continued)*

Disease	Cultural Management	Chemicals (read and follow the label)	Comments
Lesion nematodes (*Pratylenchlus* spp.)	Destroy stalks and roots (Table 8-2). Rotate with fescue.	None usually required. See Table 8-5.	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 nematodes (*Meloidogyne incognita*) (*M. arenaria*) (*M. javanica*) (*M. hapla*) (*M. enterolobii*)	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 8-5.	Rotation usually requires 2 or more years. Resistant varieties are resistant only to races 1 and 3 of *M. incognita*. Other species and races are now common in North Carolina. Observe a 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	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 to 12 fl oz/acre (8 fl oz/acre has given consistently good results) Howler (Pseudomonas chlororaphis strain AFS009) 2.5-7.5 lbs/acre Theia (Bacillus subtilis strain AFS032321) 1.5-5 lbs/acre	Easily confused with brown spot. Begin management as soon as damage is observed. The effectiveness of biological controls has not been assessed.
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	None

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.	See Table 8-6	Wash hands with soap or milk after handling tobacco. Disinfect equipment with 25% to 50% household bleach.
Tomato spotted wilt virus (TSWV)	Avoid destruction of winter weeds. Avoid planting during peak thrips flights.	None	None
Weather fleck (Ozone air pollution)	None	None	No practical control.

NOTES

9. TOBACCO INSECT MANAGEMENT

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The weather in much of the state was warm in 2024, with an extended period of dry weather and drought during most of July, followed by between 5 and 8 inches of rain in mid-August dropped by Hurricane Debby. Insect pressure was moderate to low for most of the growing season, with low budworm and hornworm pressure (<10% infestation) up until August. Tomato spotted wilt virus (TSWV) occurrence was as low as the last several years. However, tobacco thrips populations have been very high during most of the last five years. Entomologists and plant pathologists have demonstrated that virus inoculum takes several years to build up in non-crop hosts before it will cause significant infection rates in tobacco. Consistently high thrips observations in low TSWV years further suggest that virus inoculum, rather than thrips abundance alone, is an important component of high infection years. For growers concerned about thrips and TSWV management, the NC State tobacco thrips-flight model remains very accurate in predicting damaging third-generation thrips flights and recommending treatment timing. The model is available at products.climate.ncsu.edu/ag/tobacco-tswv.

By regularly scouting and applying insecticides only when insects exceed the thresholds provided in this chapter, overall yield can be protected. This practice has also resulted in fewer insecticide applications, lower production costs, and lower end-of-season pesticide residues. The scouting methods recommended in this chapter include both traditional and field-by-field methods that have been available for decades, and streamlined methods developed in 2020 designed for larger-scale growers for whom established application methods may be difficult to implement. 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

Sanitation in and around greenhouses is essential. Keep houses free of trash, supplies, equipment, and other unnecessary items. Insects and other pests can hide in or feed on non-plant 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. After transplanting is complete, remove and destroy excess plants in the greenhouse as soon as possible, as they can be a source for pests moving into fields.

Sanitation

Sanitation in and around greenhouses is essential. Keep houses free of trash, supplies, equipment, and 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. After transplanting is complete, remove and destroy excess plants in the greenhouse as soon as possible, as they can be a source 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 that are very difficult to control and for which no labeled pesticides are available. Greenhouses used for other purposes should be kept empty (fallow) whenever possible. A long, empty period just before introducing 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, as 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 that can provide insulation or harborage for pests.

Solarization

Closing the greenhouse during the summer and raising the temperature to 140°F 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 or Orthene 97 can be used at ¾ tablespoon per 3 gallons of water for each 1,000 square feet. 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 annually. Several other insecticides are labeled for use around the outside of structures or within the greenhouse on crops other than tobacco. Check with your local N.C. Cooperative Extension agent or the *North Carolina Agricultural Chemicals Manual* for specific recommendations.

A metaldehyde bait (Deadline Bullets) is labeled for control of slugs in and around tobacco greenhouses, and Sluggo (iron phosphate) baits are organically acceptable (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. Extinguish is a fire ant bait that is also labeled for use on cropland. Baits may act more slowly than other pesticides, so it is best to start bait use early when fire ant foraging is first observed. Foraging activity can be observed by placing an attractive food item, such as a potato chip or hot dog slice, near colonies on a warm day. 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 bait and then applying a drench treatment several days later. More specific recommendations for using baits to control fire ants are available in the *North Carolina Agricultural Chemicals Manual*.

PROTECTING TOBACCO IN THE FIELD

Management of Soil Insects

Wireworms. Wireworms are already present in the soil prior to transplant. Eggs are laid in the soil in the summer and early fall of the previous year, and larvae can live in the soil for several years. Wireworms damage tobacco by tunneling into the stalk below the soil surface. This may kill or stunt plants and may open 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, the yield may be reduced if growing conditions are less favorable or if certain diseases are present.

It is not possible to control wireworms in tobacco with post-transplant rescue treatments. You must decide in advance if you need to use soil-applied insecticides (Table 9-1). A preventive treatment may be justified if there is a history of wireworms, the field was weedy or fallow, or the field is heavily infested with soilborne diseases, such as black shank or Granville wilt. 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 (Capture LFR) or systemic insecticides (Admire, Platinum, Brigadier) can be used for wireworm control. Both types of insecticides 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, but not both. Whether you choose a contact or 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 advises otherwise.
- For systemic greenhouse-applied insecticides, apply materials evenly and wash them off thoroughly immediately after to move the insecticide to the root zone.
- 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	Active Ingredient (Mode of Action)[a]	Amount/Acre	Remarks
Acenthrin	acephate + bifenthrin (1B, 3A)	16 oz	Apply in transplant water.
Admire Pro	imidacloprid (4A)	1.2 fl oz per 1,000 plants	Apply to greenhouse plants 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.
Brigadier[b,c]	bifenthrin + imidacloprid (3A, 4A)	6.4 fl oz	Apply in transplant water.
Capture LFR[b]	bifenthrin (3A)	3.4–6.8 fl oz	Apply at transplant in transplant water or incorporate pretransplant into the top 6 inches of soil.
Durivo	chlorantra-niliprole + thiamethox-am (28, 4A)	1.6 fl oz per 1,000 plants	Apply to greenhouse plants 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	thiamethox-am (4A)	0.43 oz per 1,000 plants	Apply to greenhouse plants 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	thiamethox-am (4A)	1.3 fl oz per 1,000 plants	

[a] Insecticide Resistance Action Committee (IRAC) mode of action (MOA) code. Materials with the same code have the same mode of action.
[b] Capture LFR and Brigadier wireworm control data are limited.
[c] 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 they 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 tight 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% or more of the plants are damaged and live caterpillars are observed. Stand losses below 10% 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.

Less common soil pests. Growers may occasionally encounter 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 cannot be controlled after transplant, but growers should note fields where damage has occurred to develop preventative management strategies the next time they plant tobacco.

Strategies for 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. Four basic control strategies 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) should be avoided as they add costs and often lead to more problems than they control.

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 insect pests in a wide area, make individual fields less attractive to insects, and 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 insect pests and sources of 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 TSWV, practice weed control at least two weeks before transplant to prevent flushing thrips into a susceptible tobacco crop. Encouraging grassy vegetation around 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% early button. Timely topping and good sucker control reduces the attractiveness of the crop to budworms, hornworms, and aphids.
- **Postharvest:** Destroy stalks and roots immediately after harvest to reduce late-season pest population increases and 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 parasitoids. 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 difficult to exaggerate. For example, parasitoid wasps, predatory stilt bugs, and other beneficial insects combined can kill 80% to 90% of budworms and hornworms in a field. To make the most use of this free, natural control, follow these practicess:

- **Insecticide selection:** If insecticide application 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, as 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 and a highly effective predator on budworm and hornworm eggs and larvae.
- **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.

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

Table 9-2. Effectiveness of soil-applied insecticides

Material (MOA)	Wireworm	Aphid	Flea Beetle [a]	TSWV Suppresion[b]
Acephate (1B)	Not recommended	Inconsistent	Best	Not recommended
Admire and generic imidacloprid (4A)	Intermediate	Best	Best	Best
Capture and generic bifenthrin (3A)	Best	Not recommended	Not recommended	Not recommended
Platinum (4A)	Intermediate	Best	Best	Intermediate
Verimark (28)	Not recommended	Intermediate	Best	Intermediate

[a] Ratings for flea beetle control are for early-season populations.
[b] Imidacloprid suppresses TSWV by altering thrips-feeding behavior.

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 TSW infection—and this may increase yield or quality even when leaf-feeding insects are absent.

However, each year, many untreated fields never reach the threshold for the pests controlled by a systemic insecticide (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 budworms or hornworms. 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 increase pest pressures. There is always a risk that a systemic material will injure tobacco and reduce yield or quality. There have been concerns about the effect of some materials, in particular those listed in Table 9-3, on plants post-transplant. However, in most cases, post-transplant plant stunting due to insecticides is transient and is not apparent post topping. Instances where post-transplant stunting is more significant are usually due to a combination of factors, such as cool weather following transplant, or interactions between pesticides. 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.

One systemic insecticide 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 early in the season (four to six weeks post transplant), although longer activity has been observed against hornworms. Since hornworms are infrequent pretopping pests and are easily controlled with other materials, a preventive treatment targeted toward them is not advised. Because tobacco budworm populations do not necessarily occur during the period in which a transplant water application of Coragen is likely to be effective, the use pattern does not provide consistent control in North Carolina. In general, foliar insecticide applications provide the best control of tobacco budworm (Table 9-4). Growers interested in using Coragen in a transplant water application should carefully follow the label, use at least 100 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 obtain this information, scout fields weekly.

Scouting strategy. Scouting can be conducted on a field-by-field basis. This works best for small scale growers, growers with fields spread over a large distance, or growers with a few large fields. Growers then can determine if a field is to be treated based on the specific insect counts for that field.

Alternatively, a focal field can be selected for scouting and the observations in that field used to make treatment decisions for nearby fields within half a mile. This scouting strategy works best for growers with several fields close to each other, large overall acreage, or limited spray equipment. Scouting data for fields greater than half a mile away cannot be used for making treatment decisions.

Scouting methods. To scout small fields (fewer than 10 acres), make eight 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 two stops for every five acres. For fields greater than 20 acres, make 20 stops. Stops should be distributed randomly throughout the field. A random number table, list, or a route map developed before you enter the field can be useful for ensuring a random pattern. 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. You should not take samples near field borders (within 30 feet) because pests can be numerous 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. Applying insecticides that are not needed increases management costs, reduces beneficial insects, and increases the risk of excessive end-of-season pesticide residues.

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 an inch long or many small aphid colonies), recheck the field in two to three days. It is better to recheck 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.

After scouting, compare your results with the treatment thresholds established for each pest (Table 9-5) 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, remember that thresholds were developed based on relatively high-priced tobacco. When the value of the crop goes down, the economic threshold increases, assuming that the cost of pesticides remains the same. Thus, the same thresholds are more conservative now than in the past.

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

Treatment	Rate/ 1,000 plants	Total number of trials	Leaf Width—3 weeks after transplant		
			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 indicates leaves were the same size. Less than 1.0 indicates treated leaves are smaller. Greater than 1.0 indicates treated leaves are larger.

Table 9-4. Relative efficacy of selected insecticides against tobacco budworm. Data from a total of 23 site years of experiments. Individual trial data are available via Arthropod Management Tests (https://academic.oup.com/amt).

Product	Rate/acre	Active Ingredient (MOA)	Site Years	Average Control [a]
Besiege	7 fl oz	lambda-cyhalothrin + chlorantraniliprole (3A + 28)	7	83.5%
Blackhawk	1.6 oz[b]	spinosad (5)	8	84.5%
	All rates [c]		22	85.0%
Coragen, foliar	5 fl oz	chlorantraniliprole (28)	17	81.5%
Coragen, transplant water	7 fl oz		6	28.50%
Denim	8 fl oz [b]	emamectin benzoate (6)	2	88.2%
	All rates [d]		4	89.9%
Exirel	13.5 fl oz	cyantraniliprole (28)	2	85.4%
Spear-Lep + Leprotec	2 pt + 2 pt	GS-omega/kappa-Hxtx-Hv1a + *Bacilus thuringiensis* strain EVB-113-19 (32 + 11A)	4	55.1%
Steward	9.2 fl oz[b]	indoxacarb (22A)	7	75.8%
	All rates[e]		15	70.9%
Verimark, greenhouse tray drench	13.5 fl oz	cyantraniliprole (28)	3	13.3%

[a] Calculated relative to the untreated control at 6 to 8 days after treatment via Abbot's Correction.
[b] Recommended rate.
[c] 1.5 to 2.4 oz
[d] 8 and 10 fl oz
[e] 6.7, 9.2, and 11.3 fl oz

Table 9-5. 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 larvae [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% of the time. Therefore, preventative treatments against hornworms, such as those in tank-mixes with contact applications, are not recommended.

Choosing an insecticide. 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:

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

Which are the most effective insecticides to use against the pest(s) you are trying to control? If two or more insects are damaging a field, the best choice would be an insecticide that provides 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 beneficial organisms and the environment, are often the best choice. Table 9-6 shows the effectiveness of insecticide sprays against major leaf-feeding insects, and Table 9-8 shows general insecticide recommendations.

What are the hazards to the applicator and other workers? Consider the hazard presented by each option 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 low risk. 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 9-6. Effectiveness recommended of foliar insecticides against insect pests

Insecticide (MOA)	Insect Pest Control Levels			
	Aphid [a]	Budworm	Flea Beetle	Hornworm
Actara (4A)	Excellent	Not recommended	Excellent	Not recommended
Admire Pro (4A)	Excellent	Not recommended	Excellent	Not recommended
Assail[b] (4A)	Excellent	Not recommended	Excellent	Not recommended
Besiege (28, 3A)	Not recommended	Excellent[e]	Good	Not recommended
Blackhawk (5)	Not recommended	Excellent	Good	Excellent
Brigade[e] (3A)	Not recommended	Good	Not recommended	Not recommended
B. thuringiensis (11A)	Not recommended	Moderate[c,d]	Not recommended	Excellent
Coragen (28)	Not recommended	Good[e]	Not recommended	Excellent[e]
Denim (6)	Not recommended	Excellent	Not recommended	Excellent
Exirel (28)	Not recommended	Excellent	Excellent	Good
Fulfill (9B)	Excellent	Not recommended	Not recommended	Not recommended
Orthene[e] (1B)	Good	Moderate	Good	Excellent[e]
Spear-Lep[f] (32)	Not recommended	Good	Not recommended	Good
Steward (22A)	Not recommended	Excellent	Good	Excellent
Warrior[e] (3A)	Fair	Good[e]	Not recommended	Excellent

Note: Moderate also means the insecticide may be less consistent.
[a] Aphid control ratings are based on maximum labeled rates.
[b] Aphid rating for Assail is based on limited data. Assail acts as an ovicide for tobacco budworm and tobacco hornworm.
[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 the use of these materials at times when these pests are active. Check with your purchaser before using.
[f] Spear-Lep is recommended in a tank mix with a *B. thuringiensis*-containing product.

What restrictions will there be on field work? 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 stated on the label. Restricted entry periods generally range from 4 to 48 hours.

Are tobacco buyers concerned about insecticide residues? The number of materials for which buyers have residue concerns is increasing. Because of concerns for certain materials, such as carbaryl (Sevin), we no longer suggest using them in tobacco. Communicate with your intended buyer to ensure you use 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 the use of an insecticide restrict time of harvest? Regulations require a waiting period between insecticide application and harvest. The length of time varies with the insecticide and is noted on the label. For example, the pyrethroid lambda-cyhalothrin (Warrior) has a 40-day preharvest interval restriction, and bifenthrin (Brigade 2EC) cannot be applied after layby.

What effect will various insecticides have on beneficial insects? Some insecticides are more detrimental to beneficial insects than others. *Bacillus thuringiensis* products (such as DiPel) 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.

Should resistance management be considered? Insecticides kill their targets in different ways, called the "mode of action" (MOA). Chemicals that have the same MOA are grouped by the Insecticide Resistance Action Committee (IRAC, https://irac-online.org/modes-of-action/), a consortium of agrichemical industry experts, into numbered classes. Insecticides with the same IRAC MOA number have the same mode of action. Pest populations that are treated multiple times with the same MOA are more likely to develop resistance to chemicals with that MOA. Therefore, when the same pest requires more than one treatment to achieve control, growers should use a different MOA.

How much does the material cost? Cost is an important consideration, but remember 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 (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. However, 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% (1998) and 100% (1999) did not significantly reduce yields compared to tobacco kept budworm-free. Tests in 2002 and 2003 assessed the impact of budworm feeding on a plant-by-plant basis. A 100% budworm infestation significantly reduced yield in only one of six trials, and only when the infestation occurred early and there was an unusually high incidence of topping. The treatment threshold (10% of plants budworm-infested) is a very conservative and safe threshold. Do not rush into treatment.

If using insecticides, 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 third of the plant using a high volume (25 to 50 gallons per acre) spray. The spray nozzles should be as low over the bud as practical and no more than 12 inches above the bud (or about 6 inches above the uppermost leaf tips). Tobacco budworm larvae prefer to feed on young leaves, and post topping, they are typically only present on sucker growth. Do not treat after topping unless significant feeding is occurring on harvestable leaf.

Thrips and Tomato Spotted Wilt Virus

Tomato spotted wilt virus (TSWV) is moved from plant to plant by tiny insects called thrips. The word thrips is both singular and plural. Tobacco thrips, the main vector in tobacco, are usually brown or black as adults and have delicate fringed wings that look like an individual feather. Thrips are thin and much longer than they are 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, 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. Although many species of thrips exist, most of them either cannot carry TSWV or do not feed on tobacco. Moreover, even thrips that can carry the disease may not have picked up the virus from a diseased plant. Two species that do carry the virus and feed on tobacco are the tobacco thrips (Frankliniella fusca) and the western flower thrips (Frankliniella occidentalis). In most years, the tobacco thrips are the most important vector of TSWV in the early season.

The 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 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 can 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, and foliar treatments have 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 (products.climate.ncsu.edu/ag/tobacco-tswv) is effective for use in timing foliar Actigard applications to reduce TSWV incidence.

Cultural practices. Field selection and 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 transplant of tobacco. Thrips will be forced from the dying weeds into a very susceptible tobacco crop. Weeds in these adjacent 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

There are 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 (such as *Bt* for budworm and hornworm control). Others are limited for use in organic 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 9-7). 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 can be found in in the *North Carolina Agricultural Chemicals Manual*.

Some organic growers plant rows of sunflowers or sunflower-buckwheat mixtures around the tobacco field edges or through the field in the "truck rows" to attract beneficial insects that feed upon aphids. Research conducted in NC State's 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 eight rows into a field).

Table 9-7. The efficacy of select organically approved materials on key pests of flue-cured tobacco in North Carolina

Product	Active Ingredient (MOA)	Rate	Aphids	Budworms	Flea beetle	Hornworms
Aza-Direct	azadirachtin (UN)	2 pt/acre	Low	Low	Low/Moderate	Not recommended
Dipel DF	Bacillus thuringiensis kurstaki (11A)	1 lb/acre	Not recommended	Moderate	Not recommended	High
Dipel 10G Bait	Bacillus thuringiensis kurstaki (11A)	10 lb/acre (0.03 oz/plant)	Not recommended	High [a]	Not recommended	Low [b]
EcoTec +TriTek	Rosemary oil + cyper-methrin (3A)	4 pt/acre + 1.5%	Low	Low	Low/Moderate	Not recommended
Heligen	Helicoverpa zea Nucle-opolyhedrovirus strain ABA-NPV-U (31)	1.2 to 2.4 fl oz	Not recommended	Low/Moderate	Not recommended	Not recommended
GOS Neem 7-Way + Spray Clean	Neem oil + sodium hypochlorite	5% + 3 fl oz/pt neem	Low	Low	Low/Moderate	Not recommended
Pyganic 1.4EC	pyrethrins (3A)	64 fl oz/acre [c]	Low	Low	High	Low

[a] Bait must be applied directly to the bud of the plant.

[b] Result from experiment in Virginia—similar results expected in NC.

[c] The label rate range for Pyganic EC 1.4 is 16 to 64 fl oz, 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 pests are more active during warm weather, although they live through winter 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 airtight. 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 2 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: 2.5 teaspoons DiPel DF or Biobit HP per quart of water per 100 pounds of tobacco.
- Storage area: 6 teaspoons DiPel DF or Biobit HP per 2.5 gallons of water. Use half a gallon per 1,000 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 as fumigants are very hazardous and must be handled carefully 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 only those insects that are present in the treated 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 needed. The information presented here is not a substitute for pesticide label information. Follow all label-use directions, and obey all federal, state, and local pesticide laws and regulations.

Table 9-8. Conventional insecticides for remedial insect management in the field. Organically acceptable materials for insect control are listed in Table 9-7. Rates are for foliar applications only. See the* North Carolina Agricultural Chemicals Manual *for a comprehensive list of materials and application information. 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, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Green peach aphid — GREENHOUSE OR TRANSPLANT WATER APPLICATIONS Aphids are primarily pre-topping pests. Greenhouse or transplant treatments may provide control through topping, and additional foliar treatments are not typically needed. Post topping, aphids are most common on suckers or regrowth. Sucker management via contact materials or hand removal is often sufficient to control post-topping aphid populations. The threshold for green peach aphids in the field is 10% of plants scouted with 50 or more aphids on the upper leaves. Organically acceptable aphid control materials are generally less effective than conventional materials, so aphid control in organic production should be initiated upon first aphid appearance, and treatment should continue on 7-to-10-day intervals until topping. **Data on specific organic aphid controls are limited.** Organic tobacco with aphid populations should be topped as early as feasible. Post-topping sucker control is very important for aphid control in organic tobacco.	acephate, IRAC 1B (Orthene) 97	0.75 lb	24 If significant foliar contact occurs, gloves must be worn for 14 days after treatment.	3	**TRANSPLANT WATER APPLICATION.** Apply in a minimum of 100 gal of transplant water per acre. To avoid plant injury, do not exceed 0.75 lb a.i. acephate per acre. SUPPRESSION ONLY but may not provide suppression through topping. Continue to scout plants post transplant. Do not use more than 4 1/8 lb/acre Orthene (4 lb a.i./acre). This includes greenhouse, transplant water, soil, and foliar applications.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Green peach aphid — GREENHOUSE OR TRANSPLANT WATER APPLICATIONS *(continued)*	acephate + bifenthrin, IRAC 1B + IRAC 3A (Acenthrin)	16 oz	24	3	**TRANSPLANT WATER APPLICATION.** Apply in a minimum of 100 gal of transplant water/acre. To avoid plant injury, do not exceed 0.75 lb a.i. acephate per acre. **SUPPRESSION ONLY** but may not provide suppression through topping. Continue to scout plants post transplant. Do not use more than 4 lb acephate/acre). This includes greenhouse, transplant water, soil, and foliar applications. Bifenthrin provides more protection against soil pests (such as wireworms) than acephate alone.
	imidacloprid, IRAC 4A (Admire Pro)	**Rate per 1,000 plants** 0.6 fl oz	12	14	**TRANSPLANT WATER APPLICATION.** Rate is per 1,000 plants and should be converted for transplant water applications based on plant population. Proper calibration of application equipment is essential for effective transplant water applications. A metered or pressurized application system is recommended. Several concentrations of imidacloprid (1.6F, 2F, 4F, and 4.6F) are available. Read the label carefully to determine the correct rate for target pests.
	imidacloprid, IRAC 4A (Admire Pro)	**Rate per 1,000 plants** 0.5 fl oz	12	14	**GREENHOUSE TRAY DRENCH APPLICATION.** Rate is per 1,000 plants. Apply no more than 5 days before transplanting. Immediately after application, wash the material off the plants onto the potting soil. The lowest label rate is sufficient for aphid and flea beetle management. See below for recommendations for areas with high incidence of tomato spotted wilt virus (TSWV). Several concentrations of imidacloprid (1.6F, 2F, 4F, and 4.6F) are available. Read the label carefully to determine the correct rate for target pests.

***Table 9-8.** (continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Green peach aphid — GREENHOUSE OR TRANSPLANT WATER APPLICATIONS *(continued)*	thiamethoxam, IRAC 4A (Platinum) 75 SG (Platinum) SC	**Rate per 1,000 plants** 0.17 oz 0.5 fl oz	12	None given	**TRANSPLANT WATER APPLICATION.** Use lower label rate for aphids. Rate is per 1,000 plants and should be converted for transplant water applications based on plant population. Proper calibration of application equipment is essential for effective transplant water applications. A metered or pressurized application system is recommended. Make only one application of thiamethoxam per season. Thiamethoxam is also the active ingredient in Actara.
	thiamethoxam, IRAC 4A (Platinum) 75 SG (Platinum) SC	**Rate per 1,000 plants** 0.17 oz 0.5 fl oz	12	None given	**GREENHOUSE TRAY DRENCH APPLICATION.** Use lower label rate for aphids. Rate is per 1,000 plants. Apply no more than 5 days before transplant. Immediately after application, wash the material off the plants onto the potting soil OR apply in transplant water.
	chlorantraniliprole + thiamethoxam, IRAC 28 + IRAC 4A (Durivo)	**Rate per 1,000 plants** 0.6 to 1.6 fl oz	12	None given	**TRANSPLANT WATER APPLICATION.** Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo.
Green peach aphid — FIELD FOLIAR APPLICATIONS	acephate, IRAC 1B (Orthene) 97	0.5 lb	24 If significant foliar contact occurs, gloves must be worn for 14 days after treatment.	3	Use at least 25 gal per acre at 60 PSI. Using hollow-cone or small solid-cone nozzles cover the entire plant with spray. If control is not adequate within 4 days after treatment, choose another MOA for subsequent applications. Do not use more than 4 1/8 lb/acre Orthene (4 lb a.i./acre). This includes greenhouse, transplant water, soil, and foliar applications. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3 (pyrethroid) insecticides. Select other materials when available.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Green peach aphid — FIELD FOLIAR APPLICATIONS *(continued)*	acephate + bifenthrin, IRAC 1B + IRAC 3A (Acenthrin)	8 to 12 oz	24	Layby	Make no more than two foliar applications per season. Note the long preharvest interval associated with the inclusion of bifenthrin. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	acetamiprid, IRAC 4A (Assail) 30 SG	1.5 to 4 oz	12	7	Make no more than four applications of acetamiprid per season, and do not apply more than once every 7 days. Avoid using only Group 4A insecticides as foliar field applications for aphids on plants which were treated in the greenhouse with imidacloprid or thiamethoxam.
	imidacloprid, IRAC 4A (Admire Pro)	0.7 to 1.4 fl oz	12	14	Avoid using only Group 4A insecticides as foliar field applications for aphids on plants which were treated in the greenhouse with imidacloprid or thiamethoxam. Several concentrations of imidacloprid (1.6F, 2F, 4F, and 4.6F) are available. Read the label carefully to determine the correct rate for target pests.
	imidacloprid, IRAC 4A (several products) 2F	1.6 to 3.2 fl oz			
	thiamethoxam, IRAC 4A (Actara)	2 to 3 oz	12	14	Make only one application of thiamethoxam per season. Thiamethoxam is also the active ingredient in Platinum.
	pymetrozine, IRAC 9B (Fulfill) 50 WG	2.75 oz	12	14	Make no more than two applications of pymetrozine per year.
	lambda-cyhalothrin, IRAC 3A (Warrior II with Zeon Technology)	0.96 to 1.92 fl oz	24	40	NOTE LONG PREHARVEST INTERVAL. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Green peach aphid — FIELD FOLIAR APPLICATIONS *(continued)*	pyrethrins IRAC 3A (Pyganic) 1.4 EC	16 to 64 fl oz	12	0	Pyganic should be buffered to pH 5.5 to 7. OMRI-listed. Limited data. Harvest once spray has dried.
	pyrethrins IRAC 3A (Pyganic) 5.0 EC	4.5 to 15.61 fl oz			
	azadirachtin, IRAC UN (Aza Direct)	1 to 2 pt	4	0	Optimal pH range 5.5 to 6.5. OMRI-listed. Limited data.
	rosemary and peppermint oil (Ecotec Plus)	1 to 4 pt	0	0	Rate for 100-gal spray volume. OMRI-listed. Limited data.
Tobacco flea beetle — GREENHOUSE OR TRANSPLANT WATER APPLICATIONS Greenhouse or transplant treatments may provide control through topping, and additional foliar treatments are typically not needed. The threshold for foliar treatments on small, recently planted tobacco is four beetles per plant. Flea beetle populations may increase near harvest and require management if populations exceed 60 beetles per fully grown plant. Good coverage is required for effective flea beetle control in large plants. Use appropriate equipment and sufficient water volume to achieve coverage from the base to the top of the plant.	acephate, IRAC 1B (Orthene) 97	0.75 lb	24 If significant foliar contact occurs, gloves must be worn for 14 days after treatment.	3	**TRANSPLANT WATER APPLICATION.** Apply in a minimum of 100 gal of transplant water/acre. To avoid plant injury, do not exceed 0.75 lb a.i. acephate per acre. **SUPPRESSION ONLY** but may not provide suppression through topping. Continue to scout plants post transplant. Do not use more than 4 1/8 lb/acre Orthene (4 lb a.i./acre). This includes greenhouse, transplant water, soil, and foliar applications.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Tobacco flea beetle — GREENHOUSE OR TRANSPLANT WATER APPLICATIONS *(continued)*	acephate + bifenthrin, IRAC 1B + IRAC 3A (Acenthrin)	16 oz	24	3	**TRANSPLANT WATER APPLICATION.** Apply in a minimum of 100 gal of transplant water/acre. To avoid plant injury, do not exceed 1.0 lb a.i. acephate per acre. **SUPPRESSION ONLY** but may not provide suppression through topping. Continue to scout plants post transplant. Do not use more than 4 lb acephate/acre, nor more than 2 lb of bifenthrin/acre. This includes greenhouse, transplant water, soil, and foliar applications. Bifenthrin provides more protection against soil pests such as wireworms than acephate alone.
	imidacloprid, IRAC 4A (Admire Pro)	**Rate per 1,000 plants** 0.6 fl oz	12	14	**TRANSPLANT WATER APPLICATION.** Proper calibration of application equipment is essential for effective transplant water applications. A metered or pressurized application system is recommended. Several concentrations of imidacloprid (1.6F, 2F, 4F, and 4.6F) are available. Read the label carefully to determine the correct rate for target pests.
	imidacloprid, IRAC 4A (Admire Pro)	**Rate per 1,000 plants** 0.5 fl oz	12	14	**GREENHOUSE TRAY DRENCH APPLICATION.** Rate is per 1,000 plants. Apply no more than 5 days before transplanting. Immediately after application, wash the material off the plants onto the potting soil. The lowest label rate is sufficient for aphid and flea beetle management. See below for recommendations for areas with high incidence (>10%) of tomato spotted wilt virus (TSWV). Several concentrations of imidacloprid (1.6F, 2F, 4F, and 4.6F) are available. Read the label carefully to determine the correct rate for target pests.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Tobacco flea beetle — GREENHOUSE OR TRANSPLANT WATER APPLICATIONS *(continued)*	thiamethoxam, IRAC 4A (Platinum) 75 SG (Platinum) SC	**Rate per 1,000 plants** 0.27 oz 0.8 fl oz	12	None given	**TRANSPLANT WATER APPLICATION.** Use lower label rate for aphids. Rate is per 1,000 plants and should be converted for transplant water applications based on plant population. Proper calibration of application equipment is essential for effective transplant water applications. A metered or pressurized application system is recommended.
	thiamethoxam, IRAC 4A (Platinum) 75 SG (Platinum) SC	**Rate per 1,000 plants** 0.27 oz 0.827 oz	12	None given	**GREENHOUSE TRAY DRENCH APPLICATION.** Use lower label rate for aphids. Rate is per 1,000 plants. Apply no more than 5 days before transplant. Immediately after application, wash the material off the plants onto the potting soil OR apply in transplant water.
	chlorantraniliprole + thiamethoxam, IRAC 28 + IRAC 4A (Durivo)	**Rate per 1,000 plants** 1.0 to 1.6 fl oz	12	None given	**TRANSPLANT WATER APPLICATION.** Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo.
	cyantraniliprole, IRAC 28 (Verimark) SC	10 to 13.5 fl oz	4	None given	**GREENHOUSE TRAY DRENCH APPLICATION.** Rate is per acre. Use plant density to calculate greenhouse application rate.
Tobacco flea beetle — FIELD FOLIAR APPLICATIONS	acephate, IRAC 1B (Orthene) 97	0.5 lb	24 If significant foliar contact occurs, gloves must be worn for 14 days after treatment.	3	Use at least 25 gallons per acre at 60 PSI. Using hollow-cone or small solid-cone nozzles, cover the entire plant with spray. If treatment control is not adequate after 4 days, choose another MOA for subsequent applications. Do not use more than 4 1/8 lb/acre Orthene (4 lb a.i./acre). This includes greenhouse, transplant water, soil, and foliar applications. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Tobacco flea beetle — FIELD FOLIAR APPLICATIONS *(continued)*	acephate + bifenthrin, IRAC 1B + IRAC 3 (Acenthrin)	8 to 12 oz	24	3	Make no more than two foliar applications per season. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	Indoxacarb IRAC 22A (Steward EC)	6.7 to 11.3 fl oz	12	14	No more than four applications per season at no less than 5 day intervals. Don't apply more than 45 fl oz per acre per calendar year.
	lambda-cyhalothrin, IRAC 3A (Warrior II with Zeon Technology)	0.96 to 1.92 fl oz	24	40	NOTE LONG PREHARVEST INTERVAL. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	acetamiprid, IRAC 4A (Assail) 30 SG	2.5 to 4 oz	12	7	Make no more than four applications of acetamiprid per season, and do not apply more than once every 7 days. Avoid using only Group 4A materials for season-long control of insects with more than one generation. Following treatments of Group 4A materials, rotate to a different MOA before making additional applications of a Group 4A material.
	imidacloprid, IRAC 4A (Admire Pro)	1.4 fl oz	12	14	Avoid using only Group 4A insecticides as foliar field applications for aphids on plants which were treated in the greenhouse with imidacloprid or thiamethoxam. Several concentrations of imidacloprid (2F, 4F, and 4.6F) are available. Carefully read the label to determine the correct rate for target pests.
	imidacloprid, IRAC 4A (several products) 2F	1.6 to 3.2 fl oz			
	thiamethoxam, IRAC 4A (Actara)	2 to 3 oz	12	14	Make only one application of thiamethoxam per season. Thiamethoxam is also the active ingredient in Platinum.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Tobacco flea beetle — FIELD FOLIAR APPLICATIONS *(continued)*	spinosad, IRAC 5 (Blackhawk)	1.6 to 3.2 oz	4	3	Tobacco flea beetles are not listed on the Blackhawk label, but other flea beetle species are, and the active ingredient is very effective against flea beetles. Although spinosad is a naturally derived active ingredient, Blackhawk is not OMRI-listed.
	cyantraniliprole, IRAC 28 (Exirel)	13.5 to 20.5 fl oz	12	7	There is limited data on the efficacy of cyantraniliprole as a foliar treatment in tobacco.
Armyworm Armyworms are typically most common late in the growing season. Preventative treatment is not recommended.	lambda-cyhalothrin, IRAC 3A (Warrior II with Zeon Technology)	0.96 to 1.92 fl oz	24	40	NOTE LONG PREHARVEST INTERVAL. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	spinosad, IRAC 5 (Blackhawk)	1.6 to 3.2 oz	4	3	Although spinosad is a naturally derived active ingredient, Blackhawk is not OMRI-listed.
	chlorantraniliprole, IRAC 28 (Coragen)	3.5 to 7 fl oz	4	1	Field foliar application only. Transplant applications will not have sufficient longevity to affect armyworm populations. Make no more than four applications per season (with at least 3 days between applications) and apply no more than 15.4 fl oz per season.
Budworm The threshold for tobacco budworm is 10% infested plants. This threshold is very conservative, and budworms should not be treated unless infestations exceed 10%. Coverage is important for budworm management. Use one to three full cone nozzles 6 to 12 inches above bud and a minimum of 25 gal water per acre.	acephate, IRAC 1B (Orthene) 97	0.75 lb	24	3	There are many formulations of acephate. Do not use more than 4 1/8 lb/acre Orthene (4 lb a.i./acre). This includes greenhouse, transplant water, soil, and foliar applications. Acephate has some activity against tobacco budworms, but other products are more effective. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Budworm *(continued)*	acephate + bifenthrin, IRAC 1B + IRAC 3A (Acenthrin)	6 to 16 oz	24	3	Make no more than two foliar applications per season. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	chlorantraniliprole, IRAC 28 (Coragen)	5.0 to 7.5 fl oz	4	1	**TRANSPLANT WATER APPLICATION.** Rate is per acre. Transplant applications of Coragen may suppress tobacco budworm populations for 4 to 7 weeks. Proper calibration of application equipment is essential for effective transplant water applications. A metered or pressurized application system is recommended. Apply no more than 15.4 fl oz of Coragen or more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo.
	chlorantraniliprole, IRAC 28 (Coragen)	3.5 to 7.5 fl oz	4	1	**FIELD FOLIAR APPLICATION.** Make no more than four applications per season (with at least 3 days between applications) and apply no more than 15.4 fluid ounces of Coragen or more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Some purchasers may have concerns about chlorantraniliprole residues, particularly if used later in the growing season. Discuss chlorantraniliprole usage with purchaser prior to making applications.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Budworm *(continued)*	chlorantraniliprole + thiamethoxam, IRAC 28 + IRAC 4A (Durivo)	**Rate per 1,000 plants** 1.6 fl oz	12	None given	**TRANSPLANT WATER APPLICATION.** Transplant applications of Durivo may suppress tobacco budworm populations for 4 to 7 weeks. Proper calibration of application equipment is essential for effective transplant water applications. A metered or pressurized application system is recommended. Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo.
	emamectin benzoate, IRAC 6 (Denim)	8 to 12 fl oz	12	14	Do not apply more than 36 fl oz of Denim per year.
	Indoxacarb IRAC 22A (Steward EC)	6.7 to 11.3 fl oz	12	14	No more than four applications per season at no less than 5-day intervals. Do not apply more than 45 fl oz per acre per calendar year.
	cyantraniliprole, IRAC 28 (Exirel)	10 to 20.5 fl oz	12	7	There is limited data on the efficacy of cyantraniliprole as a foliar treatment in tobacco.
	lambda-cyhalothrin, IRAC 3A (Warrior II with Zeon Technology)	0.96 to 1.92 fl oz	24	40	To avoid build-up of resistance, rotate use of this product with other insecticides. NOTE THE LONG PREHARVEST USE RESTRICTION. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	lambda-cyhalothrin + chlorantraniliprole IRAC 3A + 28 (Besiege)	5.0 to 10.0 fl oz	24	40	NOTE THE LONG PREHARVEST USE RESTRICTION. Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Budworm *(continued)*	lambda-cyhalothrin + thiamethoxam, IRAC 3A + 4A (Endigo) ZC	4.0 to 4.5 fl oz	24	40	NOTE THE LONG PREHARVEST USE RESTRICTION. Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	spinosad, IRAC 5 (Blackhawk)	1.6 to 3.2 oz	4	3	Although spinosad is a naturally derived active ingredient, Blackhawk is not OMRI-listed.
	Bacillus thuringiensis, IRAC 11 (DiPel DF)	0.5 to 1 lb	4	0	There are many *Bt* formulations, including Agree, Biobit, Condor, Crymax, Deliver, Dipel, Javelin, and Lepinox. Highest-labeled rates are generally needed for budworm control. DiPel DF and many other *Bt* formulations are OMRI-listed, but not all *Bt* formulations are OMRI-listed. Carefully read the label to determine if a material is acceptable for use on organically certified plants. DiPel 10G formulation is intended to be applied as a bait directly to buds and can be more effective against tobacco budworm than sprayable formulations.
	Bacillus thuringiensis, IRAC 11 (DiPel 10G)	5 to 10 lb			
	Helicoverpa zea nucleopolyhedrovirus ABA-NPV-U IRAC 31	1.2 to 2.4 fl oz	4	0	Most effective on small larvae (under 1/2 inch); start application when first small caterpillars are observed. More than one application may be needed if large populations are present or if reinfestation occurs. Most effective at 7.0 pH. Heligen is only effective against tobacco budworm and corn earworm.
	GS-omega/kappa-Hxtx-Hv1a IRAC 32 (Spear-Lep)	1 to 2 pt	4	0	Spear-Lep is intended to be combined with a *Bt* product for proper control. Non-ionic surfactant (0.125% v/v) recommended by manufacturer. Data on Spear-Lep performance in tobacco are limited.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Cutworm Preventative insecticide applications are not recommended for cutworms because they are infrequent pests and rescue materials are effective. Scout fields in the first 4 weeks following transplant for cutworm injury and treat if 10% of plants are clipped. Cutworm treatments should be applied in a directed spray over rows in the late afternoon or at dusk, when cutworms are most likely to be active.	acephate, IRAC 1B (Orthene) 97	0.75 lb	24	3	There are many formulations of acephate. Do not use more than 4 1/8 lb/acre Orthene (4 lb a.i./acre). This includes greenhouse, transplant water, soil, and foliar applications. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	acephate + bifenthrin, IRAC 1B + IRAC 3A (Acenthrin)	6 to 16 oz	24	Layby	Make no more than two foliar applications per season. Note the long preharvest interval associated with the inclusion of bifenthrin. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	lambda-cyhalothrin, IRAC 3A (Warrior II with Zeon Technology)	0.96 to 1.92 fl oz	24	40	NOTE LONG PREHARVEST INTERVAL.
	lambda-cyhalothrin + chlorantraniliprole IRAC 3A + 28 (Besiege)	5.0 to 10.0 fl oz	24	40	NOTE LONG PREHARVEST USE RESTRICTION. Apply no more than 15.4 fluid ounces of Coragen or more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Some purchasers may have concerns about chlorantraniliprole residues, particularly if used later in the growing season. Discuss chlorantraniliprole usage with purchaser prior to making applications.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Cutworm *(continued)*	chlorantraniliprole, IRAC 28 (Coragen)	3.5 to 7.5 fl oz	4	1	Make no more than four applications per season (with at least 3 days between applications). Apply no more than 15.4 fl oz of Coragen or more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Some purchasers may have concerns about chlorantraniliprole residues, particularly if used later in the growing season. Discuss chlorantraniliprole usage with purchaser prior to making applications.
Grasshopper	acephate, IRAC 1B (Orthene) 97	0.25 to 0.5 lb	24	3	Nymphs (young) are more easily controlled than adults. There are many formulations of acephate. Do not use more than 4 1/8 lb/acre Orthene (4 lb a.i./acre). This includes greenhouse, transplant water, soil, and foliar applications. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3 (pyrethroid) insecticides. Select other materials when available.
	acephate + bifenthrin, IRAC 1B + IRAC 3A (Acenthrin)	6 to 16 oz	24	Layby	Make no more than two foliar applications per season. Note the long preharvest interval associated with the inclusion of bifenthrin. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Hornworm Treat for hornworms when five or more larvae longer than 1 inch and without cocoons are found per 50 plants. Hornworm larvae with cocoons should be considered 1/5 of a larva when counting. If treatment is necessary during harvesting, be certain to follow all labeled preharvest intervals.	acephate, IRAC 1B (Orthene) 97	0.5 lb	24	3	There are many formulations of acephate. Do not use more than 4 1/8 lb/acre Orthene (4 lb a.i./acre). This includes greenhouse, transplant water, soil, and foliar applications. Some purchasers may have concerns about acephate residues, particularly if used later in the growing season. Discuss acephate usage with purchaser prior to making applications.
	acephate + bifenthrin, IRAC 1B + IRAC 3A (Acenthrin)	6 to 16 oz	24	Layby	Make no more than two foliar applications per season. Note long preharvest interval associated with the inclusion of bifenthrin. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	chlorantraniliprole, IRAC 28 (Coragen)	3.5 to 5 fl oz	4	1	FIELD FOLIAR APPLICATION. Because hornworms are not frequent pests before topping, transplant water applications of Coragen for hornworms alone are not recommended. Make no more than four applications per season (with at least 3 days between applications). Apply no more than 15.4 fl oz of Coragen or more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Lower label rates of Coragen are likely sufficient for hornworms. Some purchasers may have concerns about chlorantraniliprole residues, particularly if used later in the growing season. Discuss chlorantraniliprole usage with purchaser prior to making applications.
	cyantraniliprole, IRAC 28 (Exirel)	13.5 to 20.5 fl oz	12	7	
	emamectin benzoate, IRAC 6 (Denim)	8 to 12 fl oz	12	14	Do not apply more than 36 fl oz of Denim per year.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Hornworm *(continued)*	lambda-cyhalothrin + thiamethoxam, IRAC 3A + 4A (Endigo) ZC	4.0 to 4.5 fl oz	24	40	NOTE THE LONG PREHARVEST USE RESTRICTION. Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	lambda-cyhalothrin + chlorantraniliprole IRAC 3A + 28 (Besiege)	5.0 to 10.0 fl oz	24	40	NOTE THE LONG PREHARVEST USE RESTRICTION. Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	Indoxacarb IRAC 22A (Steward EC) oz	6.7 to 11.3 fl	12	14	No more than four applications per season at no less than 5-day intervals. Do not apply more than 45 fl oz per acre per calendar year.
	spinosad, IRAC 5 (Blackhawk)	1.6 to 3.2 oz	4	3	While spinosad is a naturally derived active ingredient, Blackhawk is not OMRI-listed.
	Bacillus thuringiensis, IRAC 11A (Dipel DF)	0.5 to 1 lb	4	0	There are many *Bt* formulations, including Agree, Biobit, Condor, Crymax, Deliver, Dipel, Javelin, and Lepinox. Highest labeled rates are generally needed for budworm control. DiPel DF and many but not all *Bt* formulations are OMRI-listed. Read the label carefully to determine if a material is acceptable for use on organically certified plants.
	GS-omega/kappa-Hxtx-Hv1a IRAC 32 (Spear-Lep)	1 to 2 pt	4	0	Spear-Lep is intended to be combined with a *Bt* product for proper control. Non-ionic surfactant (0.125% v/v) recommended by manufacturer. Data on Spear-Lep performance in tobacco is limited.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Japanese beetle Infestations may be spotty within fields and do not typically require treatment.	acephate, IRAC 1B (Orthene) 97	0.75 lb	24	3	There are many formulations of acephate. Do not use more than 4 1/8 lb/acre Orthene (4 lb a.i./acre). This includes greenhouse, transplant water, soil, and foliar applications. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	acephate + bifenthrin, IRAC 1B + IRAC 3A (Acenthrin)	6 to 16 oz	24	Layby	Make no more than two foliar applications per season. Note the long preharvest interval associated with the inclusion of bifenthrin. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	lambda-cyhalothrin + chlorantraniliprole IRAC 3A + 28 (Besiege)	5.0 to 10.0 fl oz	24	40	NOTE THE LONG PREHARVEST USE RESTRICTION. Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	lambda-cyhalothrin + thiamethoxam, IRAC 3A + 4A (Endigo) ZC	4.0 to 4.5 fl oz	24	40	NOTE THE LONG PREHARVEST USE RESTRICTION. Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Japanese beetle *(continued)*	imidacloprid, IRAC 4A (Admire Pro)	1.4 fl oz	12	14	**FIELD FOLIAR APPLICATION.** Avoid using only Group 4A materials for season-long control of insects with more than one generation. Following treatments of Group 4A materials, rotate to a different MOA before making additional applications of a Group 4A material.
	imidacloprid, IRAC 4A (several products) 2F	3.2 fl oz			
	thiamethoxam, IRAC 4A (Actara)	2 to 3 oz	12	14	Make only one application of thiamethoxam per season. Thiamethoxam is also the active ingredient in Platinum.
Slug Slugs are only potential pests in the greenhouse and shortly following transplant. They do not present a risk to larger plants.	iron phosphate bait (Sluggo)	20 to 44 lb	0		OMRI-listed. TO AVOID PLANT INJURY, DO NOT PUT BAIT ON PLANTS.
	metaldehyde bait (Deadline Bullets)	10 to 20 lb	12		Apply at dusk to soil surface between rows and around margins of field. DO NOT PUT BAIT ON PLANTS.
Stink bug Stink bugs rarely cause economic damage to tobacco and rarely require treatment.	acephate, MOA 1B (Orthene) 97	0.5 to 0.75 lb	24	3	There are many formulations of acephate. Do not use more than 4 1/8 lb/acre Orthene (4 lb a.i./acre). This includes greenhouse, transplant water, soil, and foliar applications. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	acephate + bifenthrin, IRAC 1B + IRAC 3A (Acenthrin)	6 to 16 oz	24	Layby	Make no more than two foliar applications per season. Note the long preharvest interval associated with the inclusion of bifenthrin. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Stink bug *(continued)*	bifenthrin, IRAC 3A (Capture LFR)	3.4 to 8.5 fl oz	12	Do not apply after Layby	**FIELD FOLIAR APPLICATION.** NOTE THE LONG PREHARVEST USE RESTRICTION. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	bifenthrin + imidacloprid, IRAC 3A, 4A \Brigadier	3.8 to 6.4 fl oz	12	Do not apply after Layby	**FIELD FOLIAR APPLICATION.** NOTE THE LONG PREHARVEST USE RESTRICTION. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	lambda-cyhalothrin, IRAC 3A (Warrior II with Zeon Technology)	0.96 to 1.92 fl oz	24	40	To avoid build-up of resistance, rotate use of this product with other modes of action. NOTE THE LONG PREHARVEST USE RESTRICTION. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	lambda-cyhalothrin + chlorantraniliprole IRAC 3A + 28 (Besiege)	5.0 to 10.0 fl oz	24	40	NOTE THE LONG PREHARVEST USE RESTRICTION. Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Tomato spotted wilt virus (TSWV) suppression The materials below act on the thrips vector of TSWV. In addition to these materials, applications of acibenzolar-S-methyl (Actigard 50WG) timed to predicted thrips flights are also effective at suppressing TSWV. Consult the TSWV and Thrips Risk Forecasting Tool (https://legacy.climate.ncsu.edu/thrips) for recommendations on timing Actigard applications. Refer to the North Carolina Flue-cured Tobacco Guide for Actigard application recommendations.	chlorantraniliprole + thiamethoxam, IRAC 28 + IRAC 4A (Durivo)	**Rate per 1,000 plants** 1.0–1.6 fl oz	12	None given	**TRANSPLANT WATER APPLICATION.** Transplant applications of Durivo may suppress tobacco budworm populations for 4 to 7 weeks. Proper calibration of application equipment is essential for effective transplant water applications. A metered or pressurized application system is recommended. Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Thiamethoxam may be less effective at suppressing TSWV than imidacloprid.
	imidacloprid, IRAC 4A (Admire Pro)	**Rate per 1,000 plants** 0.8 to 1.2 fl oz	12	14	**TRANSPLANT WATER APPLICATION.** Rate is per 1,000 plants and should be converted for transplant water applications based on plant population. Proper calibration of application equipment is essential for effective transplant water applications. A metered or pressurized application system is recommended. Several concentrations of imidacloprid (1.6F, 2F, 4F, and 4.6F) are available. Read the label carefully to determine the correct rate for target pests. Imidacloprid may be more effective at suppressing TSWV than thiamethoxam.
	imidacloprid, IRAC 4A (Admire Pro)	**Rate per 1,000 plants** 0.6 to 1.2 fl oz	12	14	**GREENHOUSE TRAY DRENCH APPLICATION.** Rate is per 1,000 plants. Apply no more than 5 days before transplanting. Immediately after application, wash the material off the plants onto the potting soil. Several concentrations of imidacloprid (1.6F, 2F, 4F, and 4.6F) are available. Read the label carefully to determine the correct rate for target pests.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Tomato spotted wilt virus (TSWV) suppression *(continued)*	thiamethoxam, IRAC 4A (Platinum) 75 SG (Platinum) SC	**Rate per 1,000 plants** 0.27 to 0.43 oz 0.8 to 1.3 fl oz	12	None given	**TRANSPLANT WATER APPLICATION.** Rate is per 1,000 plants and should be converted for transplant water applications based on plant population. Proper calibration of application equipment is essential for effective transplant water applications. A metered or pressurized application system is recommended. Thiamethoxam may be less effective at suppressing TSWV than imidacloprid.
	thiamethoxam, IRAC 4A (Platinum) 75 SG (Platinum) SC	**Rate per 1,000 plants** 0.27 to 0.43 oz 0.8 to 1.3 fl oz	12	None given	**GREENHOUSE TRAY DRENCH APPLICATION.** Use lower label rate for aphids. Rate is per 1,000 plants. Apply no more than 5 days before transplant. Immediately after application, wash the material off the plants onto the potting soil OR apply in transplant water. Thiamethoxam may be less effective at suppressing TSWV than imidacloprid.
Vegetable weevil	acephate, IRAC 1B (Orthene) 97	0.5 to 0.75 lb	24	3	Treat plants in the late afternoon for best control. Spray a band over the center of the row using a good volume of water. Do not use more than 4 1/8 lb/acre Orthene (4 lb a.i./acre). This includes greenhouse, transplant water, soil, and foliar applications. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	acephate + bifenthrin, IRAC 1B + IRAC 3A (Acenthrin)	6 to 16 oz	24	Layby	Make no more than two foliar applications per season. Note the long preharvest interval associated with the inclusion of bifenthrin. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Vegetable weevil *(continued)*	lambda-cyhalothrin, IRAC 3A (Warrior II with Zeon Technology)	0.96 to 1.92 fl oz	24	40	NOTE THE LONG PREHARVEST USE RESTRICTION. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
	lambda-cyhalothrin + chlorantraniliprole IRAC 3A + 28 (Besiege)	5.0 to 10.0 fl oz	24	40	NOTE THE LONG PREHARVEST USE RESTRICTION. Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Tobacco purchasers are concerned about residues of some pesticides in cured leaf. Use caution in making applications of acephate and Group 3A (pyrethroid) insecticides. Select other materials when available.
Wireworm Wireworm treatments should be applied pretransplant in fields with a history of significant damage. If fields do not have a history of wireworm injury, greenhouse tray drench or transplant water treatments of imidacloprid or thiamethoxam will also suppress wireworm damage if they are present.	acephate + bifenthrin, IRAC 1B + IRAC 3 (Acenthrin)	16 oz	24	3	**TRANSPLANT WATER APPLICATION.** Apply in a minimum of 100 gal of transplant water/acre. To avoid plant injury, do not exceed 0.75 lb a.i. acephate per acre. **SUPPRESSION ONLY** but may not provide suppression through topping. Continue to scout plants post transplant. Do not use more than 4 lb acephate/acre). This includes greenhouse, transplant water, soil, and foliar applications. Bifenthrin provides more protection against soil pests such as wireworms than acephate alone.
	bifenthrin + imidacloprid, IRAC 3A, 4A (Brigadier)	21.75 to 25.5 fl oz	12	Do not apply after Layby	**TRANSPLANT WATER APPLICATION.** Use as described above for transplant water treatments for imidacloprid. Brigadier is not intended for greenhouse use. Data on wireworm control are limited.
	bifenthrin, IRAC 3A (Capture LFR)	3.4 to 8.5 fl oz	12	Do not apply after Layby	Apply as a pretransplant soil treatment and incorporate into 4 in. of soil OR apply in transplant water at 3.4 to 8.5 fl oz per acre. Data on wireworm control are limited.

Table 9-8. *(continued)*

Insect	Insecticide, Formulation[1] and IRAC Group	Amount of Formulation per Acre	Restricted Entry Interval (REI) (hours)	Preharvest Interval (PHI) (days)	Precautions and Remarks
Wireworm *(continued)*	chlorantraniliprole + thiamethoxam, IRAC 28 + IRAC 4A (Durivo)	**Rate per 1,000 plants** 1.6 fl oz	12	None given	**TRANSPLANT WATER APPLICATION.** Transplant applications of Durivo may suppress tobacco budworm populations for 4 to 7 weeks. Proper calibration of application equipment is essential for effective transplant water applications. A metered or pressurized application system is recommended. Apply no more than 0.2 lb chlorantraniliprole per acre per crop, which includes applications of Coragen, Besiege, and Durivo. Thiamethoxam may be less effective at suppressing TSWV than imidacloprid.
	imidacloprid, IRAC 4A (Admire Pro)	**Rate per 1,000 plants** 0.6 to 1.2 fl oz	12	14	**GREENHOUSE TRAY DRENCH APPLICATION.** Rate is per 1,000 plants. Apply no more than 5 days before transplanting. Immediately after application, wash the material off the plants onto the potting soil. Several concentrations of imidacloprid (1.6F, 2F, 4F, and 4.6F) are available. Read the label carefully to determine the correct rate for target pests. Data on wireworm control are limited.
	thiamethoxam, IRAC 4A (Platinum) 75 SG (Platinum) SC	**Rate per 1,000 plants** 0.43 oz 1.3 fl oz	12	None given	**GREENHOUSE TRAY DRENCH APPLICATION.** Use lower label rate for aphids. Rate is per 1,000 plants. Apply no more than 5 days before transplant. Immediately after application, wash the material off the plants onto the potting soil OR apply in transplant water. Data on wireworm control are limited.

[1] Some insecticides are available in several formulations. Those listed are generally the most commonly used or are readily available. Other formulations may or may not be suitable for use on tobacco or a specific pest. Check labels carefully.

10. CURING AND MECHANIZATION

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Energy efficiency is an integral part of sustainable agriculture. With the significant increase in fuel costs and the continued uncertainty in future energy costs, it is 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. 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. This chapter includes additional information on ordering, tray steam sanitation, standby power requirements, and machinery safety.

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 and increased consumption of electricity and fuel. 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.

Most 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; and 2,200 to 2,400 pounds for upper-stalk. These loading rates are typical for Long, Powell, or Taylor 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 from 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. Typical bulk densities vary from approximately 9 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 barns and boxes.

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.

If you have concerns about the relative humidity sensor accuracy, compare the wet-bulb temperature displayed on the curing control unit with a wet-bulb thermometer manually positioned in the barn. In addition, ask the ventilation system or barn manufacturer about the calibration requirements. At a minimum, it is highly recommended to compare the wet- and dry-bulb temperatures displayed on the automatic control system with actual wet- and dry-bulb thermometers positioned in the barn during curing. A simple liquid-filled glass thermometer or stem thermometer can be calibrated with a mixture of crushed ice and water. Place the thermometer in the mixture for several minutes and adjust the thermometer relative to the fixed scale to read 32°F (0°C). A wet- and dry-bulb thermometer combination called a hygrometer can also be purchased at AgriSupply or other HVAC supply vendors. The most important step is to check the relative humidity sensor accuracy in a timely manner to ensure that any issues can be corrected before the curing season begins, or you are at a critical point in the season and need the barn capacity. Inaccurate wet- and dry-bulb temperature measurements can result in significant negative effects on curing management, cured leaf quality, and fuel consumption.

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- and wet-bulb temperatures determines the relative humidity of the air. As the difference between the dry- and wet-bulb temperatures increases, the relative humidity decreases. A smaller difference indicates an increase in the relative humidity. If the air were completely saturated, which would mean the relative humidity was 100%, the dry-and wet-bulb temperatures would be equal. *The wet-bulb temperature can never exceed the dry-bulb temperature*. Table 10-1 shows the relative humidity (%) for various dry- and wet-bulb temperatures used during curing. 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%.

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

Wet-Bulb Temperature (°F)	**Dry-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 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. Growers have control of the dry-bulb temperature, relative humidity, and time variation of both during the curing process.

Yellowing involves a delicate balance between maintaining a high relative humidity and removing as much moisture as possible without excessive drying. A freshly harvested mature tobacco leaf is approximately 80 to 90% moisture content (wet basis) and 10 to 20% solids. The moisture content is highest with lower-stalk tobacco and decreases with stalk position. The leaf is alive and metabolically active during yellowing and the biochemical processes continue until terminated by high temperatures or desiccation. 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. As sufficient moisture is removed during yellowing, the drying and leaf wilting will also help to improve airflow through the tobacco. The rate and extent of the biochemical reactions are controlled by temperature and moisture. Starch conversion to sugars and the chlorophyll breakdown are independent processes, but occur simultaneously and at about the same rate. As a result, optimum sugar accumulation will occur when most of the chlorophyll has degraded and the yellow pigment becomes visible, which is a visual indicator for growers to assist them with when to make changes during the curing process.

As curing progresses, the difference between the dry- and wet-bulb temperatures increases, and the relative humidity decreases. When air is heated without changing the moisture content, both the dry- and wet-bulb temperatures will increase. The dry-bulb temperature will increase more than the wet-bulb temperature, which decreases 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, which minimizes 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 maintaining accurate control and minimizing fuel consumption require monitoring the relative humidity.

Curing experience, as well as knowledge of curing principles, is needed to produce consistently high-quality cures. Poor leaf quality is not improved during curing, even with ideal curing conditions and lots of curing experience. The final quality of very good and poor-quality leaf loaded in the barn can be significantly reduced with improper curing conditions. The potential quality of the cured leaf is determined in the field and as a result, the first step is to start with uniformly ripe tobacco. This tobacco requires less time curing and yellows more uniformly during curing. Even growers with a great deal 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, there are many questions about 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 no simple answer. Detailed curing guidelines from a late-1970s Powell Manufacturing bulk barn operating manual are posted on the Tobacco Growers Information Portal (tobacco.ces.ncsu.edu/). The manual 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 guideline is to slow down the processes of yellowing and leaf drying for tobacco that is grown under stressed conditions. The tobacco will not release moisture easily and as a result, drying too fast will negatively affect the cured leaf quality.

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 increase significantly during periods of rainy or tropical weather and decrease when cold fronts occur later in the season. As ambient conditions change significantly due to weather events, the ventilation will need adjusting to compensate.

Growers who do not measure or monitor the wet-bulb temperature are almost certain to over-ventilate 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. In addition, overventilation during yellowing may result in accelerated drying and setting the color green, especially the tobacco near the bottom of the boxes that is in contact with the air first. As the intake damper is opened more fully, 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% relative humidity), which means that some of the available heat energy in the air will be lost to the outside. 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.

Automatic damper control provides continuous monitoring of the wet-bulb temperature or relative humidity, and results 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%. At a few locations, the growers used 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, although the control system displays both the wet-and dry-bulb temperatures.

Many of the automatic ventilation control systems also have an optional monitoring system feature that transmits the dry- 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. 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 are based on your 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, here are a few guidelines:

- 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 and near the front of the curing barn. This allows easy access and 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.

BARN AND HEATING SYSTEM ENERGY EFFICIENCY

Over an extended period of time, tobacco growers have become accustomed to significant changes in conventional fuel prices and the associated fluctuations in production costs with curing tobacco from season to season. Although growers are familiar with some degree of fuel price fluctuations from year to year, the long-term energy outlook and associated costs remains uncertain. As a result, it is important to follow the annual maintenance requirements recommended by the heat exchanger, burner, and barn manufacturers to ensure they are functioning at optimum levels to minimize fuel consumption and the associated costs. The burners should be inspected annually 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 as needed to ensure proper operation. At current fuel prices and the age of most heating systems, annual maintenance must be performed to minimize fuel usage and costs. The number of qualified barn service technicians has decreased significantly over the past five years or more and as a result it may become increasingly difficult to get the proper maintenance performed on your heating system components in a timely manner. As a result, any barn heating system service work will need to be scheduled well in advance of the curing season.

Burner Efficiency

The greatest reasons for burner inefficiency are 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 also 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's 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 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. In addition, the burner firing rate (BTUs/hour) can greatly influence the efficiency of a particular heat exchanger.

Growers should arrange to 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 120°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 that compared insulated and non-insulated barn pads ranged 3% to 6%. 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 anything about an uninsulated pad now. However, 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 become hard and torn, which causes 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. 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 local Extension center for more information about this material.

Heating System Leaks

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. The test procedure utilizes a carbon dioxide (CO_2) meter to continuously measure the CO_2 level in an empty barn when the heat exchanger is operating continuously over 10 minutes. Barn testing can be conducted by independent third-party companies or individual growers who have attended a N.C. Cooperative Extension training. Additional training is not required to maintain your capacity to test barns for heating system leaks. Growers or companies that have been trained and have purchased a CO_2 meter to test barns need to maintain the meter probe calibration. The probe needs to be recalibrated by the manufacturer based on their recommended calibration interval, which is typically performed annually or every two years. Refer to the manufacturer manual or other source of information provided with the meter. The most common meter used for this application is manufactured by Vaisala, which provides the factory calibration date on the CO_2 probe. Vaisala also has an online process to send the probe back to the company for recalibration (https://store.vaisala.com/us/return-products-for-service/). 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. Many heat exchangers have been in service for over 20 years, and the average life span of a heat exchanger is 15 to 25 years. 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 and cost might increase significantly. Additional information about the recommended barn-testing equipment, meter recalibration, and testing procedures can be obtained from your local Extension center or viewed on the Tobacco Growers Information Portal.

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. For example, if two growers were paying $1.00 per gallon for LP gas, but their curing efficiencies averaged over the season were 10 pounds per gallon and 13 pounds per 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.

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 $0.10 to $0.14 per kilowatt-hour (kWh).

Table 10-3. Estimated curing cost (fuel only) for varying barn energy efficiencies and fuel cost

Fuel Efficiency (lb/gal)	$/lb Cured Leaf by Fuel Cost ($/unit)						
	0.80	1.00	1.20	1.40	1.60	1.80	2.00
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 ft of gas. A therm of natural gas has approximately 10% 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%. Green wood is approximately 50% 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 who is 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 lower 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, which results 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.

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. 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% or higher. However, if not properly tuned, they can operate at much lower values. Modern wood-fired boilers have heating system efficiencies of 80% or higher as a result of the control technologies 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 $0.50 per therm for natural gas, the equivalent cost for LP gas is $0.46 per gallon, $0.70 per gallons for fuel oil, and $70 per ton for wood chips. A few years ago, some growers were paying $0.70 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 $0.64 per gallon to be equivalent to $0.70 per therm for natural gas, assuming the heating system efficiencies are the same. 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.

LOWER-AIR PLENUM TURNING VANE

Adequate airflow in a bulk-curing barn is critical to maximize the cured leaf quality and minimize the time required to complete the curing process. Fan specifications, barn design, and the tobacco-loading characteristics (leaf orientation, container packing density) are variables that affect airflow in curing barns. Most barns have enough fan power, but the air circulation ductwork, particularly the lower air plenum, can potentially be improved to increase the fan volumetric air delivery per unit of time. Typical lower plenum heights (depth) can range from 14 to 22 inches. As the plenum height decreases, the more restriction the fan must overcome to provide the desired airflow. The air exiting the fan housing has to make an abrupt 90-degree change in flow direction. This is the case for most box barns that utilize a tube-axial fan configuration. Barns with a centrifugal fan (squirrel-cage) configuration may minimize this directional change because the orientation of the air exiting the fan housing is already turned. A turning vane installed in the lower air plenum can potentially decrease the amount of energy loss (pressure losses) associated with the high velocity air impacting the floor of the lower plenum prior to a change in flow direction. Turning vanes are sheet metal devices fabricated into a semi-circular shape and installed in the ductwork to smoothly and gradually reorient the airflow change in direction (Figure 10-1). A few barn models were manufactured with a turning vane to improve airflow, but most barns do not have a vane.

Figure 10-1. Sheet metal turning vane added to the lower-air plenum to improve airflow.

On-farm locations over the past few seasons were used to collect performance information that compared a barn with a turning vane added and an identical make barn without a turning vane. The vanes were rolled out of 16-to-20-gauge sheet metal with a radius approximately equal to the existing plenum height. The vane width and length are slightly larger the existing fan housing diameter (typically 36 inches). The locations selected load multiple barns daily, utilize automatic curing controls, and use a tube-axial fan configuration. Several locations observed a 12-to-24-hour reduction in curing time compared to an identical make barn without a turning vane. Other locations indicated limited, if any, differences in the cure duration comparing barns with and without a turning vane. Most locations that indicated a time savings benefit had a lower plenum height of 17 inches or less. A single location indicated that they observed a reduction in swell stems for some cures, particularly in the boxes near the front of the barn. Although this is not quantified, any reduction in swell stems should also reduce the labor requirements during the cured leaf market preparation. The main benefit is the time savings and the potential to gain an additional cure through the barn over the season.

Adding a turning vane to improve airflow and decrease the curing time may not be possible for all make barns due to the barn's lower air-plenum design differences and fan configurations. Additionally, a turning vane may interfere and create a problem when implementing the tobacco ordering system. However, a sheet metal turning vane that costs less than $100 per barn to install is a very low-cost technology that many growers can implement and evaluate any improvements in their barns in a single season. Barns with a lower-plenum access door at the back make it simple to add a turning vane. Otherwise, a section of the floor must be removed or some other means of access will be required. If you are interested in adding a turning vane, contact your local Cooperative Extension Center for more details.

MOISTURE ADDITION IN CURED TOBACCO

Green tobacco is approximately 80% to 90% water. At the end of the curing cycle, the tobacco is essentially 0% 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. With 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 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, while 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 the barn at 15% 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. As 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% (< 50%) efficient and require additional time.

Some growers have constructed homemade ordering systems from 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 1 hour on and 30 minutes off, but the actual duty cycle can be customized.

On-farm tests conducted in past years that compared commercial high-pressure units operated intermittently with existing systems at a given location resulted in reductions of 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 who used 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, although the output flow rate may be significantly higher than 1 gpm, which causes 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 1 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's efficiency and uniformity. However, a higher gpm may be needed later in the season when dealing with upper-stalk tobacco and the ambient temperatures that 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. In addition, implementing a timer for continuous or intermittent operation will assist in improving the ordering process control and management.

TRAY SANITATION USING STEAM

Methyl bromide is no longer available. The existing options to completely eliminate the inoculum of pathogens in used greenhouse float trays are to either purchase new trays each season, which is cost prohibitive, or to sanitize them with steam. There are some individuals and businesses that steam trays for growers, but the cost can range from $4 to $6 per acre. Multiple equipment manufacturers are making commercially available steam sanitation systems, although more growers are interested in information on 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 that it is possible to steam strays at a lower temperature for a longer period of time and still maintain 100% 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 be unable 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 were 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 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 seeding.

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 to 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. However, 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 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 a temperature and pressure rating greater than the output of the steam unit.

We constructed a steam sanitation system from commercially available components to collect on-farm performance information. The steam generator was an add-on heating unit from Northern Tool (Northern Tool Item #157495) 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 for this application. The tray container was a 24-foot commercial shipping container reduced to a length of 15 feet so that 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 foam board approximately 2 inches thick.

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 used to assist with the sanitation process. The float trays were steamed prior to reseeding their greenhouses at both 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) when 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 local 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. 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 varies with the 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

Since steam can cause serious injuries, 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 that 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 increases the risk of slipping or falling. Steam can also get into electronic devices and outlets that results in an electric shock. The system should be operated away from outlets. Be sure to cover any electrical equipment in close proximity during the process and ensure that it is dry before using. Also, do not bypass or disconnect factory installed safety features that are 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 after 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 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 power interruption. Farm operations must compare the cost of standby power equipment to the potential financial loss and inconvenience that results 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 for dry-bulb; 95°F to 105°F for wet-bulb). During these stages, tobacco will tolerate less deviation from the recommended wet- 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, 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, which results in widespread damage. The damage can 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 bypass 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. The 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 provided on the alternator’s nameplate, but this 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), although many larger size operations now operate on three-phase power. If properly connected, three-phase alternators may be used to power single-phase equipment, although 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- or 240-volt service or 115 volts for a 120-volt service. Frequency should never be less than 57 hertz or greater than 63 hertz. Deviations from these ranges can destroy the alternator and the electric motors.

Sizing the Alternator (Generator). The required capacity of the alternator depends primarily on two factors. The first factor is the size and nature of the load. Electrical loads include 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. Both loads 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, check the electric motor nameplate to confirm the size or consult the barn manufacturer. The device that consumes the most electricity in a bulk curing barn will be the fan electric motor.

The second factor to consider is if 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% or greater) 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 is 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, which endangers 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. Since the purchase of a genset with automatic transfer equipment is a major investment, 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 overhead 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 × 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% 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. 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. Although manufacturers try to ensure that machinery is as safe as possible, the nature of the work creates inherent hazards that cannot be completely removed. Knowing general safety procedures and learning specific safety information about each piece of machinery could save lives and greatly reduce pain and expense.

Flue-cured tobacco production is extensively mechanized and, as a result, many machine hazards are present. Use of 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, operators' physical or mental condition, or failing to follow safety practices. The typical operating environment can have extreme temperatures, excessive noise and vibration, and slippery conditions 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. 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 and guards) are functioning properly. Never override manufacturer 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 and trash.
- 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) 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 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 creating safer work conditions when operating agriculture machinery. Additional resources on farm safety topics and equipment specific to flue-cured tobacco production can be viewed on the N.C. Department of Labor website (www.labor.nc.gov/safety-and-health/agricultural-safety-and-health), GAP Connections website (www.gapconnections.com/resources/farm-worker-safety-videos) and on the Tobacco Growers Information Portal.

NOTES

11. PROTECTING PEOPLE AND THE ENVIRONMENT WHEN USING PESTICIDES

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Despite their usefulness, agricultural chemicals pose risk to people and the environment. We therefore 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, updated in 2015, 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 and bystanders, you must be aware of the Worker Protection Standard and comply with its requirements, including the **2024 rule about the Application Exclusion Zone (AEZ)** (see next page). 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 age 18 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. Training should be provided in a language or manner the workers and handlers can understand. Records must be kept of training provided 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 (PPE) 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 ensure that workers do not enter treated fields during REIs and that handlers do not apply a pesticide in a way that touches workers or others. Handlers must suspend their application if a worker or other person is in the **Application Exclusion Zone**. This zone is an area of 100 feet around the application equipment for aerial, air blast, fumigant, smoke, mist, and fog applications and ground-based fine spray applications; or an area of 25 feet around the application equipment for ground-based applications using medium or larger droplet sizes and sprayed from more than 12 inches above the soil surface or plant medium. A paused application must not resume until people have left the zone. Protecting against exposure requires careful scheduling of pesticide application and field work so they do not conflict. PPE requirements vary from pesticide to pesticide and may be different for applicators, handlers, mixers, and 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 0.25 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 PPE 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 requirements of the Worker Protection Standard. Consult the following resources for detailed information on compliance:

- To learn more about the 2024 Application Exclusion Zone rule, see https://www.epa.gov/pesticide-worker-safety/worker-protection-standard-application-exclusion-zone
- For a reference guide for the current Worker Protection Standard, visit www.epa.gov/pesticide-worker-safety/pesticide-worker-protection-standard-how-comply-manual
- North Carolina State University has developed an overview document for growers, the Road Map to the Worker Protection Standard for Agricultural Pesticides: https://content.ces.ncsu.edu/road-map-to-the-worker-protection-standard-for-agricultural-pesticides
- You can find detailed information on the Worker Protection Standard and a link to the entire document here: www.epa.gov/pesticide-worker-safety
- The Pesticide Educational Resources Collaborative (PERC) website lists all training resources that have been developed for the current Worker Protection Standard, as well as resources for employers about how to comply and a quick reference guide: pesticideresources.org
- To help growers comply with Worker Protection Standard and GAP requirements, North Carolina State University provides pesticide applicator training opportunities: pesticidesafety.ces.ncsu.edu

Table 11-1 lists products, common names, registration numbers, manufacturers, signal words, restricted-entry intervals (REIs), and posting and notification requirements for pesticides and growth regulators commonly used on tobacco. When there is more than one formulation or trade name of a given active ingredient, the one most commonly used is provided. Note that there may be many other formulations for some of the products listed.

This information is presented to help you to properly record and post pesticide use and to plan field operations, and is presented in good faith as a reference, 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, and weed management and sucker control for proper management.

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, and carefully consider potential effects on water and safety to humans and wildlife.

A measurement called a 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% 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. A 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) that result from a long 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 PPE) 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 the 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 include ditches, hedgerows, and woods, all of which are 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) through the skin or eyes (dermal), (2) through eating, drinking, and other hand-to-mouth behaviors (ingestion), or (3) 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 as written. 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 NC Poison Control at (800) 222-1222 (www.ncpoisoncontrol.org) and seek immediate medical attention, bringing the pesticide label with you. NC Poison Control provides 24-hour services for diagnosing and treating human illness that results from toxic substances.

ROTATE PESTICIDE MODES OF ACTION

Resistance to insect control materials is a serious issue in modern pest management; the rate of discovery of new modes of action is declining, and the agriculture community cannot rely on new discoveries to continually replace tools which have been rendered ineffective by resistance. Applying pesticides with the same mode of action (MOA) more than once per growing season can increase the risk of pest resistance to these tools. To aid growers in rotating pesticide MOA, 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 local 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: (1) the risk of a pesticide running out of a field in solution with surface water (rain, irrigation, or flooding), and (2) 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 a 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 ("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 poorly 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 100 feet of a well.
- When filling spray tanks, ensure 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% 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	4 hr	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 Sucker Control	High	Medium	Low	3	891	> 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. 62531-2 Ashta Chem	Danger Poison	48 hr	Oral and Written	Ashta Gold	Intermediate	Low	Moderate	8B	NA Inhalation danger	NA
Clomazone EPA Reg. No. 279-3158 FMC Corp.	Caution	12 hr	Either	Command	Intermediate	Medium	High	13	1,369*	> 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
Cyantraniliprole EPA Reg. No. 352-860 DuPont	Caution	4 hr	Either	Verimark Exirel	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*
Emamectin benzoate EPA Reg. No. 100-903 Syngenta Crop Protection	Danger	12 hr	Either	Denim	Low	High	Low	6	81.5	439
Ethephon EPA Reg. No. 228-659 Nufarm America	Danger	48 hr	Oral and Written	Super Boll Plant Regulator	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
GS-omega/kappa-Hxtx-Hv1a EPA Reg. No. 88847-6 Vestaron Corporation	Caution	4 hr	Either	Spear-Lep	NA	NA	NA	32	> 5,000	> 5,000
Imidacloprid EPA Reg. No. 264-827 Bayer CropScience	Caution	12 hr	Either; all greenhouse applications must be posted	Admire Pro, many others	High	Medium	High	4A	4,143	> 2,000
Indoxacarb EPA Reg. No. 279-9596 FMC	Danger	12 hr	Either	Steward EC	NA	NA	Low	22A	1,818	>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	Mammalian LD_{50}[g] Dermal
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 Macdermid Ag Solutions	Caution	12 hr	Either	Royal MH-30. many others	Intermediate	Low	Low	NA	> 5,000	> 5,000
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 hr	Either	Deadline Bullets	Intermediate	Low	Low	NA	283	>5,000
Metam sodium EPA Reg. No. 45728-16 Tamincos US, LLC	Danger	48 hr	Oral and Written	Metam CLR 42%	Intermediate	Low	Low	Z	812 Inhalation danger	> 2020
Napropamide EPA Reg. No. 70506-64 United Phosphorus Inc.	Danger	24 hr	Either	Devrinol 2 EC	High	Medium	Moderate	15	4,640	>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
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
Spinosad EPA Reg. No. 62719-523 Dow AgroSciences	Caution	4 hr	Either	Blackhawk	Low	Medium	Low	5	> 5,000	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
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, 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 or graduate students enrolled in the College of Agriculture and Life Sciences (CALS) at NC State University. Transfer students are also eligible after they are enrolled in CALS. Recipients must be planning to pursue careers in the tobacco industry—specializing in tobacco farming, corporate or university tobacco research, or Extension work related 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 will continue as long as the student maintains a "B" average.

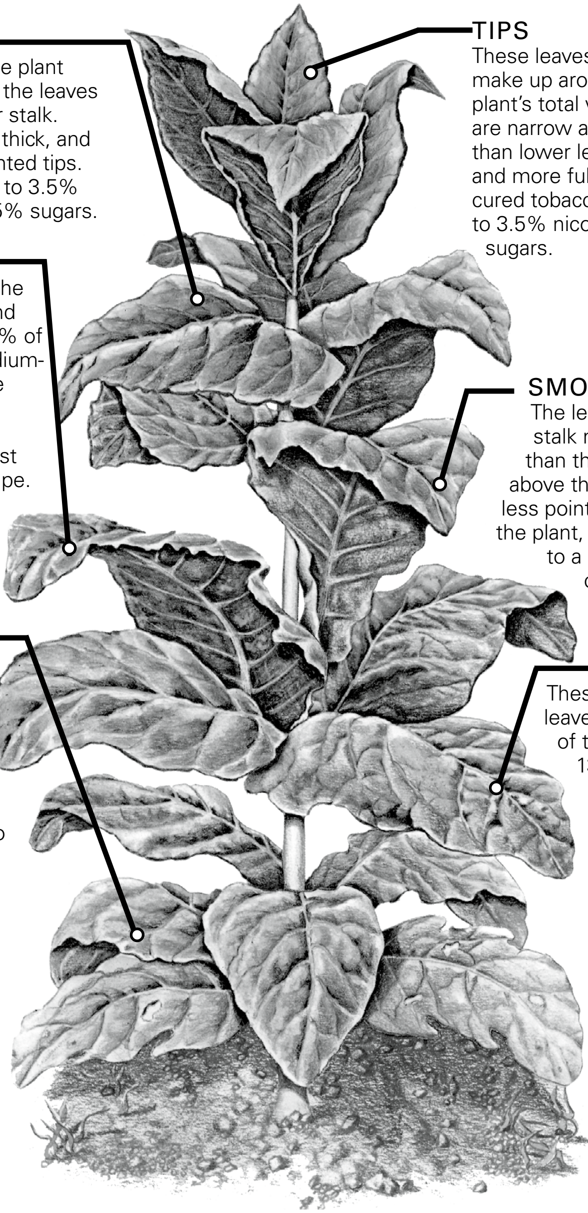
The Bond Scholarships are in memory of Fred G. Bond, who served the tobacco industry for 43 years, with 23 years as chief executive officer of the Flue-Cured Cooperative Stabilization Corporation. During his distinguished career, Bond represented flue-cured tobacco growers in the six flue-cured tobacco-growing states in many critical situations, and 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 or graduate programs are sent a letter with 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. Students with interest should mention "tobacco" in their generic scholarship application.

THE TOBACCO PLANT



LEAF
More than a third of the plant (34.5%) is made up of the leaves on the middle to upper stalk. These leaves are firm, thick, and heavy bodied with pointed tips. They contain from 3% to 3.5% nicotine and up to 15.5% sugars.

CUTTERS
The largest leaves on the plant, both in length and width, although only 8% of its weight. Thin to medium-bodied leaves from the middle of the stalk or below, cutters have rounded tips and a most desirable color when ripe. High in oil and resin content, cutters contain about 2.5% nicotine and 12% to 22% sugars.

PRIMINGS
The first leaves to ripen and to be harvested, primings make up 12% of the total plant weight and contain 1.5% to 2% nicotine and 5% to 10% sugars.

TIPS
These leaves at the stalk top make up around 18% of the plant's total weight. Tip leaves are narrow and pointed, smaller than lower leaves, yet thicker and more full bodied. Tips of flue-cured tobaccos contain from 3% to 3.5% nicotine and 6% to 6.5% sugars.

SMOKING LEAF
The leaves just above the stalk middle are thinner than the "bodied" leaves above them, and their tips are less pointed. About 7.5% of the plant, smoking leaf ripens to a rich orange color and contains about 3% nicotine and 12% to 20% sugars.

LUGS
These thin, blunt-tipped leaves around the bottom of the stalk make up 13% of the plant's weight. Lugs contain about 2.5% nicotine and 12% to 20% sugars.

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.

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 N.C. 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.

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

Published by NC State Extension

NC STATE UNIVERSITY

College of Agriculture and Life Sciences

1/25—2.25M—GM (Revised) AG-187

content.ces.ncsu.edu/flue-cured-tobacco-information

2,250 copies of this public document were printed at a cost of $3.40 per copy.