AGRONOMIC INFORMATION

T. David Reed, Extension Agronomist, Tobacco

VARIETY SELECTION

Variety selection is an important decision for profitable production of flue-cured tobacco. A high potential yield is probably more important than ever before due to reduced operating margins. However, ease of curing and specific characteristics of the cured leaf should also be considered. Varieties will differ in cured leaf color and other physical characteristics desired by purchasers (color proportion of tip leaves, etc.), but these factors are also influenced by growing conditions and curing practices. Growers should carefully consider any dramatic change in varieties grown without first trying a different variety on a limited acreage. The disease resistance of varieties varies greatly and is critical to profitable production. Detailed field histories should be maintained with specific information on past varieties planted and the level of disease occurrence.

Tobacco breeders have made tremendous progress in recent years developing resistance to the major diseases of flue-cured tobacco. Detailed information on the disease resistance of flue-cured tobacco varieties is presented in the disease section of this production guide. It is especially important that growers have a correct identification of any diseases that may be causing field losses. Black shank, Granville wilt, and *Pythium* stalk rot may be confused and the presence of nematodes can make these and other root diseases more severe than expected or symptoms may not appear as expected. To further complicate matters, there have been isolated cases of less common root diseases that are not typically evaluated for in typical variety tests. If past performance of a disease resistant variety has been less than anticipated, growers are encouraged to contact your local agriculture extension agent to investigate possible explanations and evaluate options. Proper identification of disease losses is essential to making the proper variety decision for the following season.

There are no data collected for tobacco seed sales in Virginia or official reporting of acreage planted by variety. The best information that we have is informal surveys conducted at grower meetings and consultation with dealers. Perhaps as many as 12 flue-cured tobacco different varieties were grown on any appreciable acreage in Virginia last season. The most widely planted varieties in Virginia for 2010 were K 326, NC 71, CC 27, and NC 196 with relatively equal shares between 20 and 25% each. For growers that have fields with no history of black shank, Granville wilt, or tobacco cyst nematodes, K 326 remains a popular choice given the variety's high yield potential, high quality, and ease of curing. NC 71 was one of the first Ph-gene varieties, becoming an industry standard with near immunity to race 0 black shank. CC 27 is a later release with the Ph gene plus the addition of tobacco mosaic virus (TMV) resistance with good curing characteristics. An added benefit of the Ph gene varieties is tolerance to the tobacco cyst nematode. The widespread planting of varieties with the Ph gene has significantly reduced TCN populations in rotated tobacco fields. However, continued planting of these varieties has resulted in black shank control problems due to the development of a race 1 black shank fungus. More recently, NC 196 has gained popularity given the fact that has Ph gene resistance to race 0 black shank, increased resistance to race 1, and a high yield potential. Additional information regarding black shank control and resistance ratings for both race 0 and race 1 may be found in the disease management chapter of this guide.

A number of potentially new varieties have passed the Minimum Standards Program conducted by the Flue-Cured Tobacco Variety Evaluation Committee in recent years. However, no new varieties will be commercially released for the 2011 season. Such releases are generally made based on whether a new variety will offer growers something different with regard to disease resistance, yield potential, and other agronomic characteristics.

The results from the 2010 Flue-Cured Tobacco Official Variety Trial conducted at the Southern Piedmont Center are shown in Table 1. Data are shown for yield, grade index, and relative yield. Grade index is a numerical measure of tobacco quality allows for comparisons between varieties. Relative yield is calculated based on the overall average yield of all varieties in the test. A relative yield of 100 indicates a yield approximate to the overall average of the test (NC 299, NC 297, and NC 55). Values of 104 or 96 indicate that the yield of a particular variety was 4 percent above or below the test average, respectively. When examining data in Table 1, one should remember that these data are from one year only and 2010 was not a good year for this test. Due the failure of a pond dam at the research station the test was not irrigated last season. Although the tobacco made a recovery with late season rainfall, the overall crop was generally sun-baked and immature though yields were quite high. The lack of irrigation combined with late rainfall resulted in a very late crop and late maturing varieties tended to fair better than others.

Relative yield data from the Flue-Cured Official Variety Trial for the past three seasons are presented in Table 2. The small number in parenthesis indicates the ranking of a specific variety among all of the varieties for each season. The test conducted at the Southern Piedmont Center is generally indicative of the yield potential of the different varieties grown under a well irrigated, disease free situation - except for 2010 when irrigation was not possible.

Table 1. Agronomic results from the 2010 Official Variety Trial conducted at Southern Piedmont Center - Blackstone, VA.

Variety	Yield (lbs/ac)	Relative Yield	Grade Index
CC 35	4275	118	65
CC 13	3937	109	72
NC 27NF	3936	109	79
K 326	3931	109	70
PVH 2110	3917	109	73
PVH 1118	3880	108	77
NC 71	3874	107	63
NC 196	3795	105	65
RG H51	3762	104	64
NC 72	3759	104	67
CC 700	3747	104	68
NC 102	3713	103	65
RG H4	3696	102	74
NC 37NF	3687	102	78
NC 291	3662	101	70
NC 606	3651	101	77
CC 33	3643	101	66
NC 299	3602	100	67
NC 297	3596	100	68
NC 55	3590	100	61
K 394	3583	99	70
RG 17	3581	99	76
CC 27	3572	99	60
Speight 234	3559	99	65
K 399	3541	98	70
CC 37	3524	98	74
GL 939	3521	98	79
VA 119	3505	97	71
K 149	3485	97	64
CC 67	3451	96	69
Speight 220	3417	95	69
PVH 1452	3411	95	67
VA 116	3402	94	67
Sp. NF3	3397	94	73
Sp. H20	3395	94	72
K 346	3377	94	73
NC 471	3322	92	65
PVH 1596	3303	92	68
Speight 225	3262	90	68
Speight 168	3213	89	69
NC 810	3174	88	61
Speight 227	3164	88	59
Speight 236	3127	87	63
Test average	3580		69

Table 2. Relative yields for Flue-Cured Tobacco Official Variety Trials conducted at the Southern Piedmont Center near Blackstone, Virginia for 2008-2010.

Variety	Relative Yield and Ranking within Year			3-yr Avg. Relative Yield
	2010	2009	2008	
CC 35	118 *(1)*	110 *(5)*	110 *(2)*	113
CC 13	109 *(2)*	98 *(29)*	106 *(6)*	104
NC 27NF	109 *(2)*	107 *(10)*	101 *(18)*	106
K 326	109 *(2)*	108 *(9)*	106 *(6)*	108
PVH 2110	109 *(2)*	106 *(12)*	100 *(23)*	105
PVH 1118	108 *(6)*	101 *(20)*	106 *(6)*	105
NC 71	107 *(7)*	109 *(7)*	102 *(16)*	106
NC 196	105 *(8)*	112 *(1)*	104 *(11)*	107
RG H51	104 *(9)*	95 *(33)*	104 *(11)*	101
NC 72	104 *(9)*	106 *(12)*	107 *(3)*	106
CC 700	104 *(9)*	110 *(5)*	100 *(23)*	105
NC 102	103 *(12)*	103 *(17)*	98 *(26)*	102
RG H4	102 *(13)*	101 *(20)*	98 *(26)*	100
NC 37NF	102 *(13)*	96 *(33)*	---	---
NC 291	101 *(15)*	109 *(7)*	111 *(1)*	107
NC 606	101 *(15)*	99 *(28)*	91 *(35)*	97
CC 33	101 *(15)*	105 *(14)*	---	---
NC 299	100 *(18)*	103 *(17)*	104 *(11)*	102
NC 297	100 *(18)*	107 *(10)*	107 *(3)*	105
NC 55	99 *(20)*	99 *(26)*	104 *(11)*	101
K 394	99 *(20)*	112 *(1)*	99 *(25)*	103
RG 17	99 *(20)*	100 *(24)*	97 *(29)*	99
CC 27	99 *(20)*	112 *(1)*	111 *(1)*	107
Speight 234	99 *(20)*	91 *(38)*	92 *(32)*	94
K 399	98 *(25)*	96 *(31)*	90 *(38)*	95
CC 37	98 *(25)*	112 *(1)*	106 *(6)*	105
GL 939	98 *(25)*	100 *(24)*	92 *(32)*	97
VA 119	97 *(28)*	97 *(29)*	105 *(10)*	100
K 149	97 *(28)*	101 *(20)*	103 *(15)*	100
CC 67	96 *(30)*	104 *(15)*	---	---

--- Continued ---

Table 2. Relative yields for Flue-Cured Tobacco Official Variety Trials conducted at the Southern Piedmont Center near Blackstone, Virginia for 2008-2010. (Cont'd)

	Relative Yield and Ranking within Year			3-yr Average
Variety	2010	2009	2008	Rel. Yield
Speight 220	95 *(31)*	92 *(36)*	101 *(18)*	96
PVH 1452	95 *(31)*	104 *(15)*	---	---
VA 116	94 *(33)*	101 *(20)*	101 *(18)*	99
Sp. NF3	94 *(33)*	91 *(38)*	91 *(35)*	92
Sp. H20	94 *(33)*	85 *(41)*	96 *(30)*	91
K 346	94 *(33)*	92 *(36)*	91 *(35)*	92
NC 471	92 *(37)*	93 *(35)*	85 *(40)*	90
PVH 1596	92 *(37)*	96 *(31)*	---	---
Speight 225	90 *(39)*	80 *(44)*	92 *(32)*	87
Speight 168	89 *(40)*	99 *(26)*	88 *(39)*	92
NC 810	88 *(41)*	90 *(40)*	98 *(26)*	92
Speight 227	88 *(42)*	103 *(19)*	101 *(18)*	97
Speight 236	87 *(43)*	81 *(43)*	95 *(31)*	88

GREENHOUSE TRANSPLANT PRODUCTION

Greenhouse tobacco transplant production remains the standard for the industry and growers have become quite accustom to growing transplants. Only a very small amount of any tobacco type in Virginia is still grown with transplants from traditional plant beds. Relatively few tobacco transplants are imported into Virginia. Transplants are generally produced on the farms where they are to be transplanted or purchased from greenhouse transplant growers in Virginia. Actual production problems have been relatively minor and not widespread in recent years. The most common production concerns include: soilless mix issues, spiral root seedlings, fertilizer salts injury, algae growth, and various pest occurrence. Greenhouse management practices described in this guide are intended to provide the basics for successful greenhouse production.

The incidence of spiral root seedlings has declined in recent years as seed coating materials have evolved to better match the requirements of the tobacco seed and the wetting properties of our commonly used greenhouses mixes. A spiral root seedling may occur when the emerging root tip is damaged and does not function properly to establish a young seedling. The single most important factor that a grower can do to reduce spiral roots is to avoid over packing of the soilless mix into trays. Such over packing will result in excessively wet media in the trays and this can often impact seedling emergence. In general, spiral root seedlings will be reduced when using an automatic tray filling line with a rolling dibbler. The goal is to fill trays as uniformly as possible. However, under the best of circumstances spiral root seedlings may occur due to seed related factors. Results of a greenhouse test in conducted in 2010 to compare the performance of three commercial seed lots of the one variety are shown in Table 3. All trays were filled and seeded in a similar manner. Spiral root seedling incidence ranged from 3 to 17% and closely matched observations of the same seed lots in grower greenhouses. The impact of the spiral roots was apparent in the percentage of usable transplants as well as small seedling and observed seedling mortality.

Table 3. Seed performance trial results of three commercial seed lots of one variety. Test was conducted at the Southern Piedmont Center in Spring 2010, Blackstone, Va. Data shown are averages of six replications.

Seed lot	14 dy seedling emergence	Spiral root seedlings	Usable transplants	Small seedling	Seedling mortality
	------------------------------		(%)		------------------------------
A	93.1	17.1 a	75.9 b	13.5 a	4.9 a
B	93.1	3.3 b	84.9 a	6.8 b	1.4 b
C	91.0	10.3 a	79.0 ab	12.4 a	2.9 a

Results of this trial reinforce the observation that seed pellet factors still play a role in the incidence of spiral root seedlings. Previous research has shown that an average of one-third of these will survive to produce usable transplants, one-third will survive but are too small to transplant, and one-third will not survive.

The commonly used commercial <u>soilless media</u> used for tobacco transplant production are generally similar in their physical and chemical properties. When a problem does occur, it is not usually a common occurrence but limited to individual greenhouses or just a few. This would indicate that something unusual has occurred with a relatively limited quantity of media. Such could occur during manufacture, transport, at the dealer, or on the farm. Although not common, problems can occur with excessively wet or dry mix, sticks or other debris impacting tray filling, and inadequate wetting chemical agents. Growers should always keep lot numbers from their greenhouse media in case a problem does occur. The use of old media should be avoided since the chemical wetting agent degrades over time and this can impact the amount and uniformity of media wetting in the trays (wicking). Growers need to be mindful of the condition of greenhouse media when purchasing and avoid product that is either too wet or dry. Media should be stored so to avoid excessively high temperatures and drying. Whenever possible, bags should be kept wrapped in plastic until seeding time to preserve proper condition. Water should not be added to bags of mix unless expressly directed by the manufacturer.

Algae growth on the media surface is a common occurrence and excessive growth that covers the seed can be a concern. Other than tray sanitation, there is actually very little growers can do to prevent algae growth and algae seldom has any significant impact on seedling growth. The best strategy is to provide conditions as favorable as possible for seed germination and early seedling growth. The intention is to allow for seedlings to grow as rapidly as possible and eventually shade out any algae growth.

Research Trial to Evaluate Timing of Initial Fertilization

A research trial was conducted at the Southern Piedmont Center in 2010 to evaluate the timing of initial fertilization on seedling performance and usable transplants. Two commercial tobacco greenhouse media were compared: Carolina Choice and Sunshine LT-5. Fertilizer (100 ppm N) was added to bays at seeding, 1 day after seedling (1 DAS), 5 DAS, and 14 DAS. There was little difference observed between the two brands of media (Table 4). The timing of initial fertilization did not have an effect on 14-day plant stand or the number of spiral root seedlings. Fertilizer timing did impact other factors. Delaying fertilization to 5 DAS decreased seedling mortality and increased the percentage of usable transplants. This response was greater with Carolina Choice mix.

Table 4. Results of greenhouse fertilization timing study conducted at the Southern Piedmont Center, 2010. Data shown are averages of six replications.

Timing of initial fertilization	14-dy stand	Usable transplants	Spiral roots	Small seedlings	Seedling mortality
Carolina Choice		------------------- (%)	-------------------		
At seeding	94	82 b	0.8	3.3 b	9.3 a
1 DAS	95	84 b	1.0	6.8 a	5.3 ab
5 DAS	97	91 a	1.3	3.5 ab	2.3 b
14 DAS	97	92 a	1.5	3.8 ab	1.8 b
Sunshine LT-5					
At seeding	95	86 b	3.5 a	6.5	3.3
1 DAS	96	89 ab	1.0 ab	5.3	2.5
5 DAS	96	90 a	0.5 b	4.0	1.8
14 DAS	95	92 a	3.0 a	2.8	1.0

Data values in the table are significantly different for a brand of media when followed by a different letter.

Media samples (see Figure 1) were repeatedly collected from the trays over the period of time when seedlings are susceptible to that fertilizer salts injury (usually first 3 weeks after seeding). The measure of the fertilizer salts content in the growing medium is measured as electrical conductivity (Ec) and can be expressed in many different units, including millisiemens (mS) as shown below. The results of this study did not show a substantial difference in Ec between the two brands of media tested and trends over time for the different fertilization treatments were similar. However, the impact of earlier fertilizer addition to the float bays was apparent. Past research has indicated that fertilizer salts injury is most likely to occur between 14 and 21 days after seeding (DAS) where Ec values are above 3.0 mS. Values greater than 3.0 were observed for both media where the fertilizer was added at seeding or 1 DAS. Although seedling mortality was not too severe in this trial, this is consistent with the levels of mortality observed with these treatments. Adding fertilizer 5 and 14 DAS did not result in Ec levels above 3.0 and the observed seedling mortality was not likely to be related to fertilizer salts. Delay of fertilization to 14 DAS resulted in a depression in the Ec values and levels did not reach that on earlier treatments by 23 DAS. Although, this may not always result in slower seedling growth, there is the possibility for lower leaves to turn pale as the seedlings near the time of the first clipping and this can create conditions that favor the development of foliar diseases.

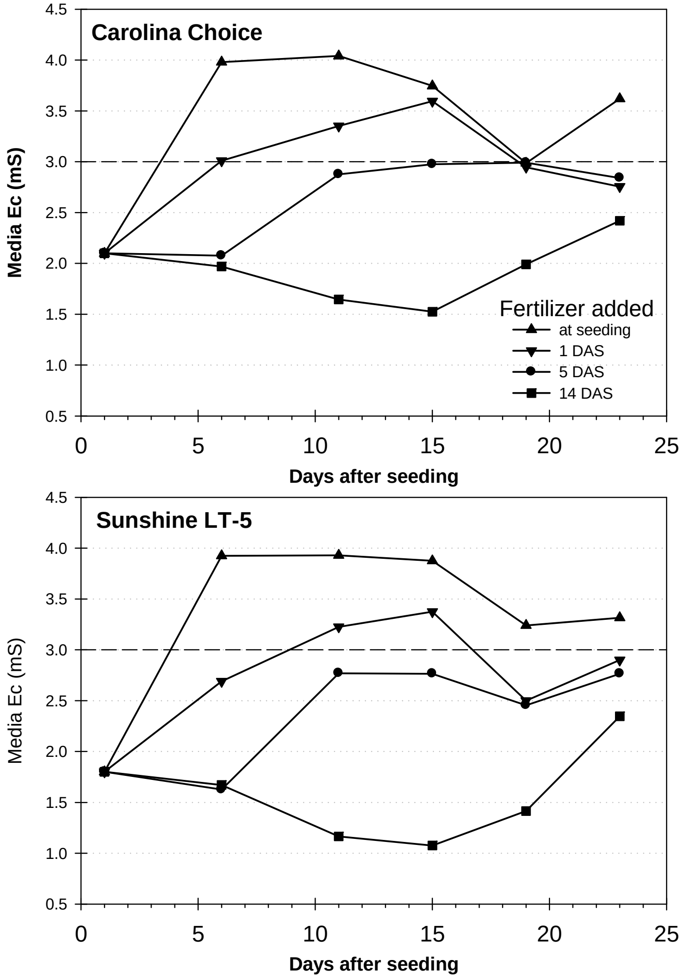

Figure 1. Fertilizer salts (Ec) for four fertilizer timing treatments with two different brands of media. Ec measured of solution extracted directly from media in tray cells. Data for Carolina Choice and Sunshine LT-5 are shown in the upper and lower graphs, respectively. Test conducted at the Southern Piedmont Center, 2010.

Growers are familiar with measuring fertilizer levels in bay water and the testing of levels actually in the media as shown in the research described above is also a valuable management tool. The procedure used in the Virginia tobacco extension program to test media is a direct extraction of water from the media in the trays. Growers interested in using this procedure to monitor their greenhouse fertilizer salts levels may contact their local extension agent or refer to the following web page (http://www.arec.vaes.vt.edu/southern-piedmont/index.html) for details.

Greenhouse Management Practices

The following is a brief description of the important management practices required for successful greenhouse production.

1. Sanitation
   Sanitation is the primary means of pest control available to greenhouse tobacco producers. Four important areas for sanitation include: the area in and around the greenhouse, people entering the greenhouse, float trays, and clipping equipment and the clipping operation. Specific information on sanitation is presented in the Disease Control chapter of this guide.

2. Ventilation and Air Circulation
   Ventilation is necessary to reduce to amount of moisture that naturally accumulates inside the greenhouse and to prevent the occurrence of enormously high temperatures. Brief openings of the side curtains early in the morning and in late afternoon are particularity effective in removing moisture laden air before condensation occurs. Air circulation within the greenhouse is beneficial to reduce temperature stratification, reduce condensation on the underside of the greenhouse cover, remove moisture from the plant canopy, and evenly distribute greenhouse gases. The use of horizontal airflow (HAF) or a polytube system is highly recommended to provide adequate air circulation.

3. Temperature Control
   The most demanding period for heating is during the seed germination period. Until maximum germination is obtained, the minimum temperature should be maintained at 70 to 72^{o}F. Extended periods of cooler temperatures will delay germination and may decrease the uniformity in the size of the seedlings. After germination, the minimum temperature may be initially reduced to 60-65^{o}F and later to 55^{o}F. Preventing high temperatures is perhaps of even greater importance. Young seedlings are particularly sensitive and the temperature should not be allowed to reach 95^{o}F during the 2- to 4-leaf stage. As seedlings grow they are better able to withstand increasingly higher temperatures. Although, to reduce stress on the seedlings, the temperature should not be allowed to exceed 100^{o}F.

High temperatures place greater stress on the tobacco seedlings due to increased water evaporation of and the resulting concentration of fertilizer salts on the surface of the growing medium.

Recent research conducted by Dr. David Smith at NCSU has investigated how flue-cured tobacco varieties differ in their germination response to temperature. This research focused on NC 71, which has been characterized as being inconsistent in germination when examined across a large number of greenhouses. Results demonstrated that NC 71 is especially sensitive to temperature conditions. Although a fluctuation in day to night temperatures was beneficial, only moderately excessive daytime temperatures can induce seed dormancy, resulting in delayed germination. The best germination was obtained for NC 71 with a temperature regime of 68 and 85^{o}F.

<u>Avoid seeding too early</u> to reduce the cost of greenhouse heating. High quality transplants can be grown in seven weeks in most situations; though, some growers have found eight weeks may be necessary with 338-cell trays. An added benefit of not seeding too early is that some pest problems may be avoided by minimizing the time that plants are in the greenhouse. Many growers seed their greenhouse when labor or seeding equipment is available. If this occurs during a period of very cold weather, one may decide to provide only minimal heat (prevent freezing) for a few days until better weather conditions occur and less heating will be necessary. Research conducted for three years in Virginia has provided excellent results with providing for only a 40^{o}F night time temperature and keeping the greenhouse cool during the day (open) for a period of three to five days. This allows for seed pellets to soften without beginning seed germination. Afterwards, normal heating can be started. This has been especially beneficial in reducing spiral root seedlings.

Greenhouse temperatures should be measured at plant level in one or more locations that are representation of the entire greenhouse. The use of a recording thermometer to measure daily high and low temperatures is an excellent management practice. Thermostat settings for heating and cooling should be made of the basis of thermometers within the immediate environment of the plants.

4. <u>Media And Tray Filling</u>

Media and tray filling may be the source of the greatest number of problems for Virginia greenhouse tobacco producers in recent years. Dry cells and spiral roots are each related to media and the tray filling operation. Assuring that all cells within a tray are uniformly filled and that all trays are similar will improve the uniformity in seed germination and seedling growth. Cells must be completed filled for their entire depth to wick properly and prevent dry cells; but over packing of the cells must be avoided to prevent the occurrence of spiral root plants. Proper moisture content of the mix is critical for adequate tray filling and the use of a premoistened medium is highly recommended. Better plant stands are generally obtained with a mix having a dry consistency rather than a mix with increased moisture and thus a heavier consistency. The mix needs only enough moisture to keep it from falling through the trays before floating. If trays wick properly, watering over the top should not be necessary to assist with seed germination. However, if trays are watered, only a fine mist should be used to prevent packing and waterlogging of the medium.

5. Fertilization

Fertilizers used in float greenhouse transplant production are formulated to function with a soilless growing medium. Such fertilizers should contain at least 50 percent of their nitrogen as nitrate-N and should contain only a minimal amount of urea. Also important to proper fertilization is an accurate estimation of fertilizer solution concentration. In addition to using the correct fertilizer material, proper fertilization requires an accurate estimation of fertilizer solution concentration to ensure that seedlings are not injured by excessive fertilizer salts. The amount of fertilizer necessary for a float bay is determined by the volume of water in a bay, the fertilizer analysis, and the desired nutrient level of the float bay. Additional information on fertilization is presented on page 19.

6. Water Quality

Water quality is a critical factor to consider with greenhouse production. Although water sources across the flue-cured tobacco producing area of Virginia pose little difficulty for most growers, scattered cases of water quality problems have occurred for some growers. The only means of predicting such problems is through water testing. When having water analyzed it is important to have the results interpreted for plant production properties rather than as drinking water.

7. Clipping

Clipping is an essential management practice for direct-seeded greenhouse tobacco production. Begin clipping when plants are at least 2 inches to the bud. If seedling growth is unusually uneven, earlier clipping will allow smaller plants to catch up. Research conducted in Virginia indicates that the timing of the first clipping, the severity of clipping, and the number of total clippings does not have a significant impact on the stem diameter of the transplants. However, the above factors were important in controlling the growth rate of the seedlings and the size of the field-ready transplant. Very early clipping (1.5 inches to bud or less) resulted in shorter than desired transplants.

Suggested Clipping Program

- Begin clipping when plants are 2 to 2.5 inches tall (bud height)
- Set mower blade at 1 to 1.5 inches above bud
- Clip on a 3-day interval between the first 3 clipping dates and every 5 days thereafter

Plant clippings must be collected to reduce the likelihood of disease development and spread throughout the entire greenhouse. The mower used to clip plants should be thoroughly cleaned and sanitized with a 50% chlorine bleach solution following each use.

The above description of greenhouse tobacco transplant production is greatly abbreviated. Additional information is available from your local Extension agent and is detailed in a "Float Greenhouse Tobacco Transplant Production Guide", VCE Publication No. 436-051.

Float Fertilization Programs

The suggested fertilization schedule for greenhouse tobacco transplant production has been changed for recent seasons. This is the result of research trials conducted the past year and extensive observation of grower greenhouses over the past several years. Such a change was warranted due to the relatively high fertilizer charge of the brands of greenhouse mixes that have gained in popularity in recent years. Furthermore, some of the newer, popular flue-cured tobacco varieties have a tendency for slow and uneven seedling emergence making them more subject to injury from fertilizer salts. The new suggested fertilizer program is intended to reduce the potential of excessive fertilizer salts build-up while not impacting early seedling growth.

Suggested Greenhouse Tobacco Fertilization Schedule

1. Add 150 ppm N 3 to 5 days after seeding
2. Maintain water level at 75% of the original depth for the first 3 weeks
3. Refill bays to original depth and add 100 ppm N at 4 weeks after seeding in preparation for initial clipping

Though seedling injury or mortality is not necessarily common, the most likely timing for the occurrence is during the third week after seedling before root grow into the water. A potential cause can be avoided by not allowing the bay water levels to fall below 75% of the original depth during the first 3 weeks after seeding thus not allowing the fertilizer to become concentrated.

The total of both applications is the equivalent of 250 ppm N based on the original depth of water in the bay (usually 4 inches). For example: using a 16-5-16 fertilizer, a total of 20.8 oz per 100 gal. (250 ppm N) would be needed with 12.5 oz per 100 gal. (150 ppm N) for the first application and 8.3 oz per 100 gal. (100 ppm N) for the second. Under normal conditions, no additional fertilizer beyond the total of 250 ppm N should be necessary. However, if the greenhouse season is prolonged due to early seeding or late transplanting, a late season addition of 75 to 100 ppm N may be needed to maintain adequate seedling nutrient levels.

The primary drawback of delaying fertilization until after the trays are floated is the difficulty in adequately mixing the fertilizer throughout the entire float bay. To insure even mixing of fertilizer throughout the float bay: dissolve fertilizer in buckets of water, add fertilizer at several locations throughout the bay, and use pumps to circulate water and distribute the fertilizer throughout the bay. Handheld conductivity meters (e.g. DiST4 or TDR Tester 4) are excellent tools to verify that fertilizer is evenly mixed throughout the entire float bay and that the desired concentration is obtained. The nutrient solution should be checked in several locations along both the center walkway and side curtains.

Growers accustom to using fertilizer injectors can continue to do so with the above fertilizer schedule. The most practical method would be to add fertilizer to the bay 1 to 3 days after seeding with adequate mixing in the bay water. The injector would be used to add 125 ppm N with each later addition of water to the bay. An alternative would be to fill bays to initial depth of 2 in. and allow trays to wick. The following day, bays would be filled to a depth of 4 in. injecting a 300 ppm N fertilizer solution for a final concentration of 150 ppm in the bay. Later additions of water would contain a concentration of 125 ppm N through the injector.

Calculation of Water Volume and Fertilizer Concentration

1. The number of gallons of water in a float bay may be calculated by:

$$\text{length (ft)} \times \text{width (ft)} \times \frac{\text{depth (in)}}{12} \times 7.48\ \text{gal/ft}^3$$

Example: $96\ \text{ft} \times 16\ \text{ft} \times \frac{4\ \text{in}}{12} \times 7.48 = 3829\ \text{gal}$

2. The amount of fertilizer required per 100 gal of water is calculated by:

$$\frac{\text{desired nutrient concentration (ppm)} \times 1.33}{\text{nutrient content of fertilizer (\%)}}$$

Example: $\frac{150\ \text{ppm N}}{16\%\ \text{N}} \times 1.33 = 12.5\ \text{oz per 100 gal}$

Usable Greenhouse Transplant Yield Research

The impact of seed, media, and fertilization on the yield of usable transplants was investigated in research trials conducted on-farm and at the Southern Piedmont Center. The timing of initial float bay fertilization (150 ppm N) was found to have the greatest impact on usable transplants. Fertilization at seeding resulted in an average seedling mortality of 15% compared to 6% where fertilizer was added three days after seeding. Delaying fertilizer addition until after seeding and floating of the trays resulted in 5 to 15% more usable transplants, depending on the particular seed and media combination. The primary benefit of adding fertilizer after trays are initially floated is to minimize the accumulation of excessive fertilizer salts in the media. Seedling mortality observed during the third week after seeding is frequently a result of excessive fertilizer salts. Fertilization was not found to impact the occurrence of spiral root seedlings. Seed, media, and the interaction of these two factors were related to the account of spiral root seedlings.

A series on-farm greenhouse trials conducted in 2009 followed up on the timing of fertilizer addition as well as the impact of media and seed source on useable transplants. In this study, fertilizer was added at 3 or 14 days after seeding and not significant differences were observed in seedling performance or useable transplants (Table 5). Comparing four brands of media, small differences were observed in both useable transplants and small transplants and not differences were observed between the two sources of seed for K 326 used in this study (Table 6). Only minimal numbers of spiral root seedlings were observed with these tests with flue-cured tobacco. In an accompanying study with burley tobacco in the same greenhouse, an overall level of 7.0% spiral root seedlings were observed. Of these, 34% resulted in useable transplants, 19% were consider too small for transplanting, and 47% died before transplanting.

Table 5. Seedling performance and useable transplants resulting from a test with two times of initial fertilizer addition and four brands of media. Owen Greenhouse, Pittsylvania County, 2009.

	14-day Emergence	21-day stand	Useable transplants	Small transplants
	------------------------ (%)	------------------------		
Fertilizer addition				
3 DAS	91.0	95.5	88.7	6.4
14 DAS	92.4	95.5	89.2	5.9
Brands of media				
Beltwide	89.1	95.9	85.2 b	10.1 a
Carolina Choice	90.4	95.2	88.0 ab	6.2 ab
Southern States Coir	94.5	95.9	90.6 a	4.4 b
Sunshine LT5	92.8	95.0	92.1 a	3.2 b

Table 6. Seedling performance and useable transplants resulting from a test with two seed sources (K 326) and five brands of media. Owen Greenhouse, Pittsylvania County, 2009.

	14-day Emergence	21-day stand	Useable transplants	Small transplants
	------------------------ (%)	------------------------		
Seed source				
Cross Creek	93.8 b	96.1	92.0	3.8
Gold Leaf	96.1 a	95.7	91.3	4.8
Brands of media				
Beltwide	94.1	97.5	88.1	7.4 a
Carolina Choice	96.4	96.7	91.9	4.1 ab
Southern States Coir	93.8	95.0	91.3	4.3 ab
Sunshine LT5	93.4	95.8	93.9	2.0 c
Southern States	96.0	96.1	92.0	3.7 ab

FERTILIZATION

The basic principles of flue-cured tobacco fertilization have been established by decades of research, but the subject has received much greater attention in recent years due to dramatic increases in the cost of fertilizer. Such increases in cost have provided growers with greater reason to examine their overall soil fertility program and how they fertilizer their tobacco. Any soil fertility program should begin with soil testing. Lime should be applied according to soil test recommendations. The amounts of phosphorus (P_2O_5) and potash (K_2O)fertilizer should follow soil test levels.

A cost effective tobacco fertilization program begins with the selection of the complete grade fertilizer product based on soil P levels. Phosphorus contributes greatly the cost of fertilizer, and therefore; the lowest P grade fertilizer product to meet the soil test recommendation should be the most economical. Fields with a history of tobacco will usually tests at a medium plus (M+) to high level for soil P due to past applications of high P fertilizer products. Over application of P will not improve crop performance, but will continue to build-up high soil P levels and potentially contribute to environmental contamination through soil runoff into watersheds. Historically, the tobacco grade fertilizer with the lowest P level has been a 6-6-18 product. However, a 6-3-18 grade is now available and should be considered as a more economical option for soils testing very high (VH) to high (H) for soil P. In addition, research conducted in Virginia has shown 6-3-18 to be suitable for soils testing with medium (M) P level when used in combination with a high P starter fertilizer supplying 4.5 to 5 lbs/ac of P_2O_5.

The most appropriate sidedress fertilizer product is dependent on how much potash is recommended based on the soil test level. If sufficient potash can be supplied with the complete fertilizer, then a N only product supply can be used. The traditional tobacco sidedress sources: nitrate of soda (16-0-0) and soda-potash (15-0-14) are no longer available. If additional potash is required, products such as 14-0-14 (all nitrate-N) and 13-0-14 (majority ammonical-N) are available. A blended 15-0-14 product N predominately as ammonical-N may also be available. Calcium nitrate (15.5-0-0) is the primary N only sidedress product available. The use of liquid nitrogen solutions has been tested and are effective if applied properly. Accurate fertilizer applicator calibration is important and the material should be incorporated into the soil for successful use a tobacco sidedresser. Other products containing various combinations of ammonium nitrate, ammonium sulfate, and/or urea are not suggested for use on flue-cured tobacco.

Tobacco Fertilizers

Historically, complete tobacco fertilizers (NPK) have been formulated to supply at least 50% of the total N as nitrate-N. Doing so ensures a more precise availability of the nitrogen to the plant, regardless of soil and environmental conditions. However, due to the cost and availability of basic fertilizer ingredients, tobacco fertilizers containing only 25% nitrate-N have been marketed in recent years. Research in Virginia with tobacco fertilizers with 50, 25, and 0% nitrate-N has not shown the reduced nitrate-N content to have a significant impact on either yield or quality of the cured tobacco. If the lower nitrate-N content is a concern, growers still have the option of using an all nitrate-N sidedress product to minimize the total amount of ammonium-N applied to the crop. Ammonium-N is naturally converted to nitrate-N for uptake by the plant. Therefore, application of a 25% nitrate-N fertilizer should not be excessively delayed beyond transplanting.

Tobacco fertilizers have traditionally been ammoniated products where the basic ingredients are melted and mixed to produce individual fertilizer granules that are as uniform in their content as possible. Another cost saving measure has been the use of blended tobacco grade fertilizer products. Blending produces a product that is as uniform a mixture of different fertilizer sources as possible. The quality of any blended fertilizer is dependent on the capacity of the fertilizer blender to provide a uniform product.

The practice of blending a complete fertilizer (NPK) with a sidedress fertilizer and working a single application is discouraged. Blending two dissimilar fertilizer products can result in a lack of uniformity. Furthermore, a single early application of fertilizer subjects all to potentially leaching rains and makes any necessary adjustment more difficult. Split application of a complete fertilizer and a sidedresser provides the nutrients to the cop when they are needed and the grower has greater control over the availability.

A third traditional property of tobacco grade fertilizers is a limitation on chlorine or muriatic sources (potassium chloride). Chlorine is a factor that impacts the chemical quality of the tobacco by affecting the burn rate of tobacco as well as the curability of air-cured tobacco types. This remains an important issue to the industry and growers must not try to save on fertilizer expense by using fertilizer products containing excessive chlorine.

Soil Testing

Only through soil sampling and soil testing can the pH and nutrient status of soils be determined and the most cost effective fertilization program followed. Fields used for tobacco production should be soil sampled every three years to monitor changes in soil pH. Soil testing and liming according to recommendations are critical to avoid either a low pH situation or an excessively high pH that results from over liming. Overliming can increase the possibility of certain disease problems (black shank and black root rot) and cause an imbalance of certain micronutrients; *though this should not be considered as a justification for not liming according to soil test recommendations*. The most common soil fertility problem associated with tobacco production in Virginia is low pH. As soil pH falls below 5.0, the availability of most soil nutrients may become limiting and elements such as manganese and aluminum can become toxic to tobacco. Furthermore the efficiency of applied fertilizers is reduced by low soil pH as shown below. Fertilizer efficiency is considered to be optimum at a pH of 7.0; though this pH is not considered optimal for tobacco. The desired pH range for flue-cured tobacco is 5.7 to 6.2.

	Fertilizer Efficiency		
Soil pH	**Nitrogen**	**Phosphate**	**Potash**
7.0	100%	100%	100%
6.0	**89%**	**52%**	**100%**
5.5	77%	48%	77%
5.0	**53%**	**34%**	**52%**
4.5	30%	23%	33%

Failure to maintain a soil pH within the desirable range of 5.7 to 6.2 results in reduced fertilizer efficiency and perhaps increased fertilizer costs due to the over application of fertilizer necessary to compensate for reduced nutrient availability.

Nitrogen

Tobacco plant development, and more importantly leaf ripening, are directly affected by the availability of soil nitrogen. The cropping history and rotations of most typical tobacco fields precludes little carryover of nitrogen to be available to tobacco. As a result, the N requirement for flue-cured tobacco is supplied primarily through chemical fertilizers. Control of the amount and timing of N directly impacts the ripening and the curability of flue-cured tobacco. Inadequate N results in both low yield and quality as the plant does not develop and mature properly. However, the application of too much N is more likely to occur. Excessive N delays ripening and is associated with tobacco that is undesirable in color (KL, KF, GK, etc.), high in nicotine, and is of generally poor quality.

Harvesting unripe tobacco affects curing costs by lengthening the yellowing time and thereby delays the turnaround time for curing barns. Excessive nitrogen may have secondary effects on the cost of production by increasing sucker growth as well as the susceptibility or severity of the crop to late season insect pests and disease outbreaks.

There is no reliable soil testing procedure for determining nitrogen needs as there is for phosphorus, potassium, and other nutrients. It is well recognized that soils differ in their ability to hold nitrogen. Some of the more important soil characteristics affecting N availability are organic matter content, soil texture, and depth to subsoil. Previous cropping history, seasonal rainfall, and variety must also be considered in determining nitrogen rates. Fields with deeper, sandy topsoils require more nitrogen than those with shallower, heavier textured topsoils. For sandy loams soils of average fertility, suggested nitrogen rates for different topsoil depth are as follows:

Topsoil depth (in.)	**Nitrogen rate (lbs/ac)**
0 to 12	50 to 60
12 to 18	60 to 70
18 to 24	70 to 80

Adjustment for Leaching

Leaching is the loss of certain nutrients as a result of excessive water moving (percolating) through the root zone. Many producers often confuse drowning and associated root damage with fertilizer leaching. Leaching is seldom a problem on heavier textured soils or on soils with a hardpan within 10 to 12 inches of the surface. It is not uncommon for nitrogen and potassium to move down to clay and then be absorbed later as root growth continues. Adjustment for leaching in this case usually results in over fertilization and a crop that is slow to mature and difficult to cure.

When leaching does occur, the reapplication of both nitrogen and potassium may be necessary. The quantity of nitrogen and potassium required will depend on the amount of water that percolates through the plow layer and the stage of plant growth at the time this occurs. Although research information on nutrient replacement from leaching is limited, the information in Table 4 (taken from N. C. Agric. Ext. Serv. Pub. AG-187) may be used as a general guide for making leaching adjustments.

Table 7. Nitrogen Adjustment for Excess Water[a]

Topsoil depth (to clay) (in.)	Estimate amount of water percolated through soil (in.)[b]	% of applied N to replace after transplanting ---weeks--- 1 to 3	4 to 5	6 to 7
Less than 10	1	0	0	0
	2	20	10	0
	3 or more	30	20	0
10 to 6	1	30	20	0
	2	45	30	10
	3 or more	60	40	15
17 or more	1	50	25	15
	2	75	35	20
	3 or more	100	45	25

[a]For each lb. of N used as an adjustment for leaching, use about 1 lb. of potash (K_20) where recommended potash levels as a base application have been used.

[b]Excess water is that quantity percolating through the soil after the water-holding capacity of the soil has been satisfied.

Applications of fertilizer to replace nutrients lost through leaching should be made as soon as possible after leaching rains occur. Waiting until deficiency symptoms develop in the crop before applying supplemental fertilizer will decrease the likelihood of a positive response to the fertilizer.

Phosphorus and Potassium

Phosphorus is probably the nutrient used more excessively in tobacco fertilization in Virginia. Repeated applications of larger quantities of phosphorus than plants can absorb, and with essentially no loss from leaching, has resulted in a general buildup of this nutrient. Soil analyses of tobacco fields conducted by the Virginia Tech Soil Testing Laboratory indicated that approximately 97% of the soils had a medium or higher phosphorus level. Extensive testing in Virginia and other states has shown that on soils with a medium or high phosphorus level, 40 pounds of phosphorus (P_20_5) per acre are adequate to give maximum production and maintain the soil phosphorus levels. Growth responses of tobacco to phosphorus application are observed more frequently early in the growing season than they are in final yield and quality.

Potassium requirements of tobacco are relatively high, and a high potassium content in flue-cured tobacco impacts acceptable smoking characteristics of the tobacco. Soils vary in their supply of available potassium, depending upon the parent material, previous fertilization, and cropping history. Approximately 100-175 pounds of potash (K_20) per acre are adequate for most soil conditions. Potassium may be lost by leaching from the root zone in extremely sandy soils.

Due to the many factors necessary to consider when making fertilizer recommendations for a particular field, data in the following table can be used only as general recommendations for phosphorus (P_20_5) and potassium (K_20).

Soil Test Category	Pounds suggested per acre P_20_5	Pounds suggested per acre K_20
L	230*	150-175
	60-100	
M	60-100	100-150
H	40	100
VH	40	100

*Basic application; to build up soil phosphorus may be broadcast and plowed-in or disked-in before planting. The 230 lb P_20_5/A can be obtained from 500 lb/A of 0-46-0.

Calcium and Magnesium

If the soil pH is maintained within the desirable range of 5.7 to 6.2 with dolomitic limestone, the available levels of calcium and magnesium will generally be sufficient to meet the needs of the crop. Otherwise, 40 to 50 lb/A of Ca and about 30 lb/A of available magnesium oxide (MgO) are needed from the mixed fertilizer.

Micronutrients

The need for the application of micronutrients such as boron, copper, manganese, and zinc has not been demonstrated sufficiently with tobacco to warrant general applications. It is definitely known that if applied at excessive rates, these elements are toxic to tobacco. Though not likely to occur, boron is the micronutrient most likely to be deficient for tobacco. Generally 0.25 pound of elemental boron per acre (approximately 2.5 pounds of borax) is sufficient to correct or prevent such deficiencies.

Sidedress Fertilizer Evaluation

Growers have lost two popular tobacco sidedress fertilizers in recent years: 16% nitrate of soda and 15-0-14. Tests were conducted in 2006 to investigate available sidedress products. Data from the test conducted at the Southern Piedmont Center are reported in Table 6.

Table 8. Agronomic results of a sidedress fertilizer comparison conducted at the Southern Piedmont Center in 2006.

Sidedresses	Yield (lbs/A)	Grade Index	Price ($/lb)
13-0-14	3892	87.3	1.47
14-0-14	3736	86.0	1.46
15-0-14	3614	85.0	1.43
15.5-0-0	3408	86.7	1.45
CN-9	3213	88.0	1.47
UAN-30	3872	85.3	1.44
CN-9 plus K-Mag	3459	87.0	1.47
UAN plus K-Mag	3552	88.0	1.48

Complete fertilizer was applied in two bands after transplanting at a rate of 750 lbs/A to supply 45 lbs/A N and 135 lbs/A of potash.

The soil test for potash for the test site indicated that no additional potash was necessary with sidedress application. All sidedress treatments were applied at the rate to provide an additional 28 lbs/A of N. Final rates of potash varied according to the sidedress materials, as well as calcium and magnesium. K-Mag was applied at 127 lbs/A to supply 28 lbs/A of potash, comparable to treatment applied with the 14-0-14 treatment.

Yield results were variable, possibly due to excessive rainfall that occurred and no significant differences were observed between the treatments. Average price and grade index were more consistent and doesn't show any practical difference among the treatments. Results of these show the sidedress treatments to be equal and the decision to choose between them should be based on cost, ease of application, and past experience.

Transplant Starter Solutions

The benefit of a high phosphorus starter fertilizer in the transplant setter water results from the ready availability of P at the stage in crop development when the nutrient be most limiting. Transplant starter fertilizers should contain a greater proportion of P_2O_5 than N and potash (i.e.. 10-52-8, 9-45-16, 12-48-8, etc.) and research has shown a rate of 4.5 to 5 lbs P_2O_5 per acre to be sufficient and not result in crop injury. The use of high P transplant starter fertilizer can be expected to provide more rapid and uniform early season growth. Such can be beneficial when cultivating and will most likely result in earlier, and more uniform topping. However, these effects do not persist through harvest and no yield response should be expected. The results of a comparison of transplant starter fertilizers are described in tables below. The test evaluated starter fertilizers using both plant bed and greenhouse-grown transplants. Treatments tested included:

Trt. No.	Product	Analysis	Application rate
1	Untreated	--	--
2	Exceed	10-10-10	2 qts/a
3	Jump-Start	8-31-4	2 qts/a
4	Charge	8-32-5	2 qts/a
5	Pro-Sol	10-52-8	10 lbs/a
6	Miller	12-48-8	10 lbs/a

The products tested differ in analysis (N:P:K) and no attempt was made to apply similar nutrient levels with each product. Products were applied at suggested rates; and therefore, nutrient levels are not equal among the treatments.

Measurement of plants in the field indicated that Trts. 3 - 6 (high P) resulted in more rapid early season growth than observed with the low P fertilizer (Trt. 2) or untreated plants (Trt. 1). As plants neared topping stage, differences between the treatments tended to diminish. However, plants in Trts. 3 - 6 did come into top earlier than those in Trts. 1 and 2. There was no apparent difference in the response of plant bed and greenhouse-grown transplants to the fertilizers. Such early season growth responses did not result in any significant difference in the yield of the treatments for both plant bed and greenhouse transplants (see Table 9).

Table 9. Topping and yield data for six transplant water treatments applied to plant bed and greenhouse float transplants, Southern Piedmont AREC, 1993.

Starter fertilizer	Percent of plants topped by July 19		Yield (lbs/a)	
	GH	PB	GH	PB
Untreated	33	30	3456	3471
Exceed	23	30	3365	3400
Jump-Start	69	88	3094	3424
Charge	59	64	3440	3525
Pro-Sol	81	88	3122	3399
Miller	86	59	3169	3356

GH = greenhouse and PB = plant bed grown transplants

Fertilizer Calculations

(1) Calculating nutrient rates

A **6-3-18** fertilizer is **6%** N, **3%** P_2O_5, and **18%** K_2O (potash)

Example:

700 lbs/ac of 6-3-18 would supply:

42 lbs/ac N	or	700 lbs/ac x 0.06 N
21 lbs/ac P_2O_5	or	700 lbs/ac x 0.03 P_2O_5
126 lbs/ac K_2O	or	700 lbs/ac x 0.18 K_2O

(2) Calculating fertilizer rate to obtain a desired nutrient rate

Example:

30 lbs/ac N from 13-0-14 would be supplied by:

231 lbs/ac or $\frac{\text{30 lbs/ac N}}{\text{0.13 N}}$

CROP ROTATIONS AND COVER CROPS

Crop rotation is one of the most effective and inexpensive methods known to increase the efficiency of flue-cured tobacco production. Crop rotation improves soil structure and nutrient balance, increasing the efficiency with which tobacco plants can utilize fertilizer and soil water. Continuous tobacco culture, even in the best of fields, promotes soil erosion and loss of soil structure, which will eventually reduce the capacity of plants in such fields to obtain enough plant food and water for maximum production. In addition, crop rotation is an excellent practice for control of tobacco diseases, insects, and weeds. Not only does crop rotation reduce losses in yield and quality to these pests, but it also reduces the need for expensive pesticides, thus reducing production costs. Crop rotation can, therefore, increase net economic returns to producers by increasing the yield and quality from each field and by reducing the costs of producing flue-cured tobacco.

Special attention should be given to the crop immediately preceding tobacco in the rotation. For example, leguminous crops should not immediately precede flue-cured tobacco because the amount of nitrogen from the crop and the time of its availability varies widely and the following tobacco crop may be affected.

The conservation compliance provision of the Food Security Act of 1985 discourages production of crops in highly erodible fields where the land is not carefully protected from erosion. If crops are produced in such fields without an approved soil conservation system, producers may lose their eligibility for certain U.S. Department of Agriculture program benefits. Contact your local Natural Resources Conservation Service (NRCS) office for more information or for soil conservation planning assistance.

Some examples of rotation plans commonly used in the flue-cured tobacco producing area of Virginia include:

- 1-year rotation
  tobacco followed by small grain or ryegrass cover crop,
- 2-year rotation
  1st year - tobacco followed by small grain and fescue or ryegrass,
  2nd year - grass
- 2-year rotation
  1st year - tobacco followed by small grain
  2nd year - small grain cut for silage and followed by grain sorghum, followed by a winter cover crop,
- 3-year rotation
  1st year - tobacco followed by small grain and fescue.
  2nd year - grass
  3rd year - grass

Seed beds for cover crops should be medium smooth, but not level. Small grains, or a combination of small grains and a grass, should be seeded as soon as possible after the second disking of tobacco roots. Early seeding of the cover crop is important to allow the cover crop to grow as much as possible during the fall. The soil surface should allow a maximum number of tobacco roots to remain exposed, even after seeding the cover crop. Crops and seeding rates for common cover crops are: RYE or WHEAT - 1 to 1 ½ bu/A; BARLEY - 2 to 3 bu/A; DOMESTIC RYEGRASS -20 to 25 lb/A.; TALL FESCUE - 15 to 20 lb/A.; SORGHUM-SUDAN HYBRID - 25 to 30 lb/A; GRAIN SORGHUM - 5 to 7 lb/A. When seeded with small grain, the seeding rate for ryegrass and fescue should be reduced to 15 lb/A.

Cover crops should be plowed under while still young and succulent, generally from mid-to late-March. Temporary nitrogen deficiency, as well as other problems, may be encountered if cover crops are plowed under late in the spring, after the plants within the cover crop have become tall and woody. If the sod of the cover crop is dense, it may be necessary to disk thoroughly in order to tear up the sod prior to plowing.

SUCKER CONTROL

Flue-cured tobacco should be topped when 40 to 50 percent of the plants reach the elongated button stage of flowering. Remaining plants should be topped as early as practical reaching the button stage. Allowing tobacco to remain untopped for up to three weeks after reaching the button stage will reduce yields 20 to 25 lb per acre per day. Late topping increases the number of pretopping suckers that must be removed as well as the chance of plants blowing over in a windstorm.

The height at which to top the plants will depend primarily on seasonal conditions, variety, and, to some extent, on the fertility level of the soil. Optimum leaf number is generally in the range of 18 to 22 leaves per plant.

MH Residues

Residues of MH have long been a concern for the tobacco industry and this factor is especially critical for tobacco sold for international markets. Virginia has historically had some of the lowest MH residues levels of any tobacco grown in the U.S. This has largely been due to the hand application of flumetralin products such as Prime+. However, this is a more labor intensive procedure and worker safety is a significant concern. The majority of growers in Virginia such hand application methods and this probably accounts for at least a third of the total crop grown.

Residues of MH will be an even bigger issue in 2011 given the increased residue levels that occurred on the 2010 crop and the indication by at least one buying company of no residue tolerance for MH in 2011. Severe drought and excessively hot weather played a large role in the elevated residues of 2010 and growers will need to strength their efforts to manage for tobacco for acceptable MH residue levels. Guidelines and suggestions for minimizing MH residues and managing suckers without MH are given below.

Guidelines to Minimize MH Residues

1. Make only 1 application of a labeled rate of MH. Do not make split applications of MH even at reduced rates since the second application will likely increase residues present in later harvests.

2. Observe the preharvest interval (7 days) following MH application.

3. Consider the addition of flumetralin to a sequential sucker control program. These products may be substituted for the last contact application, tankmixed with MH, or applied alone after MH (usually 3 to 4 weeks later).

Applying flumetralin in place of the last contact has been shown to be effective and can be used to effect MH residues by <u>delaying MH until after the first harvest and reducing the rate</u> to 1 gal per ac (1.5 lbs a.i.) or less.

The MH application should be made soon after the first harvest in order to allow for naturally weathering (rainfall, heavy dews, etc.) of MH residues from leaf surfaces.

4. Maximize the effectiveness of contact fatty alcohols by limiting excessive growth prior to their application. It is important to make the first application before pretopping suckers have grown too large (greater than 1 in. long). The first application of a C8 / C10 fatty alcohol mixture should be made at a 4% concentration (4 gal. to 96 gal. of water) and later applications should be made at 5% (5 gal. per 95 gal.).

5. The use of coarse spray tips (TG3-TG5-TG3) and low pressure for MH applications results in coarser droplets that result in less wetting of the underside of the leaves and thus not as exposed to rainfall and dews.

6. Make certain of the concentration of your MH product as formulations may contain either 1.5 or 2.25 lbs of MH per gal. The 1.5 lb formulation has traditionally been the product of choice in Virginia though either is acceptable if the correct application rate is used...

7. Don't add spray surfactants to MH applications. Product labels for MH do not state either their usefulness or necessity. Research has not shown their effectiveness in increasing rainfastness.

<u>Suggestions for MH-Free Sucker Control</u>

Dropline application of flumetralin has been long proven to be an effective alternative to the use of MH and specific details are described later as Program II. Worker safety and following label requirements with regard to PPE must be a consideration.

More recently, over-the-top spray applications of flumetralan have been successfully used in place of MH. Application of flumetralin should follow 2 or 3 applications of a fatty alcohol. Although labeled up to 1 gal. per ac, 2 to 3 qt/ac of flumetralin will be sufficient in most circumstances. If 3 qts are used, this should be spilt as two applications with 2 qts applied 1 week after the last contact and followed with 1 qt 3 to 4 weeks later.

Flumetralin does not provide the true systemic activity of MH and therefore the spray material must contact a small sucker in every leaf axil. This may not be feasible with crooked or windblown stalks. Likewise, spray nozzles must be positioned properly over the plants for optimum control. This best achieved by spraying the same number of rows as the crop is transplanted.

Chemical Sucker Control Materials

Three types of chemicals are currently available for sucker control. Growers should have a basic understanding of how the various chemicals work in order to most effectively use them.

1. Contacts (fatty alcohols) quickly kill suckers by burning and must come in contact with the suckers to be effective. Suckers should begin to turn brown within an hour of contact application. A sufficiently concentrated solution of contact material is required to obtain adequate sucker control. Use a 4% solution or 2 gal. in 48 gals of water.

   The strength of a contact fatty alcohol product is dependent on carbon chain length of the fatty alcohols. Products traditionally used in Virginia are a mixture of C_6, C_8, C_{10} and C_{12} alcohols while products containing only C_{10} alcohols are available. To avoid possible injury, C_{10} products should be used at lower concentrations than mixed alcohol products (3 and 4% concentration of a C_{10} product would be comparable to 4 and 5% concentration of a mixed alcohol product, respectively).

2. Systemic sucker control chemicals or maleic hydrazide (MH) restrict sucker growth physiologically by stopping cell division. The only growth made after MH is applied is in the expansion of cells already present in the plant. To reduce MH residues on the cured tobacco, only one application of up to the labeled rate of MH must be applied per season. Wait at least one week between MH application and harvest.

3. Products that have a local systemic mode of action stop cell division in a localized area and must wet the sucker buds in each leaf axial to be effective. The primary local systemic material flumetralin and is sold under the trade names of Prime+, Flupro, and Drexalin Plus. Affected suckers will have a yellow, deformed appearance.

Precautions with contacts:

1. Control is achieved when suckers are small (not over one inch long).
2. Never spray foam from tank; this will increase the likelihood of burning leaves.
3. Do not spray extremely succulent tobacco (tobacco with a light green to creamy white bud area). This indicates a fast rate of growth.
4. Rain within an hour after application of contacts may reduce their effectiveness.
5. In order to kill both primary and secondary suckers, contact solutions should not be applied at concentrations less than 4%. It may be

necessary to increase the concentration to 5% when applications are made under cool overcast weather conditions.

Precautions with local systemics:

1. Rain occurring within 2 hours after spraying may reduce effectiveness.
2. Applications to leaning plants, wet plants, or wilted plants may reduce effectiveness.
3. Applications made before the elongated button stage of growth may result in chemical topping or distortion of leaves that were too immature at time of application.
4. Sucker buds must be directly contacted to obtain control. Control is reduced if suckers are allowed to grow too large before application (greater than 1 in.).
5. Flumetralin residues may carryover in the soil to injure small grain and corn, and has been reported to stunt early season growth of tobacco when used with dinitroaniline herbicides such as Prowl. Fall disking and deep tillage are suggested to mitigate this potential.

Precautions with systemics:

1. Do not apply during the hot part of the day when leaf stomata are closed.
2. Rain within six hours after application of MH may reduce control. Research has shown that if a significant rain occurs more than three hours after application, only a half rate of MH should be reapplied to maintain good sucker control.

EPA WORKER PROTECTION STANDARDS

Read and follow all label directions regarding EPA Worker Protection Standards (WPS). Growers must follow requirements for personal protective equipment (PPE) and restricted entry intervals (REI). Hand topping following an over-the-top contact application will generally provide the best level of sucker control as the flower serves to funnel the material down the stalk to contact each leaf axil.

Suggested Sucker Control Programs

Program I. Sequential Method

1. Apply contact sucker control chemical (4% concentration) before topping when approximately 50 to 60% of plants reach the button stage. A small percentage (5%) of plants should be chemically topped by this application.
2. A second contact application (5% concentration) should be made 3-5 days after the first. Fields having irregular growth will require a third application (5% concentration) 5-7 days later.
3. About 5 to 7 days after the last contact, apply one of the following alternatives:

    a) MH (only one application per season); or
    b) FST-7, Leven-38 or a contact and MH tank mix; or
    c) tank mix of MH with flumetralin
    d) apply flumetralin (up to 1 gal per acre but 2 to 3 qts is suggested)

4. Flumetralin may be substituted for the last contact application and delay an application of a reduced rate of MH until after the first harvest.
5. If control of late season sucker growth is necessary, one of the following alternatives may be applied 3-4 weeks after MH application:

    a) Flumetralin
    b) 5% concentration of contact material

Program II. Individual Plant Method with a Flumetralin

Apply flumetralin with a dropline, backpack, or jug when plants reach the elongated bud stage. Usually two or perhaps three trips are required to remove tops and treat all plants in a field. Individual plants should not be treated more than once. **Growers are reminded to comply with all label directions regarding worker protection standards (WPS).**

Whether applied with jugs or with droplines, hand application of sucker control chemicals is problematic in regard to worker exposure to pesticides and issues related to worker protection standards (WPS). Complying with personal protection equipment (PPE) requirements for WPS is challenging for hand application of sucker control chemicals.

Sucker Control Spray Tip Options

Historically, 3 hollow cone nozzles arranged with a TG-5 in the center and a TG-3 on either side have been used for contact sucker control applications. With a spray pressure of 20 psi, a desired application rate of

50 gpa is obtained with a travel speed of approximately 3.8 mph. This speed is too fast for many field conditions in Virginia thus impacting the level of sucker control obtained. Using smaller spray tips, the desired application rate can be obtained at a reduced travel speed. Doing so will improve sucker control by allowing the spray operator to deliver the spray material to every plant and hopefully contacting every leaf axil. The following table gives the spray application rate (gpa) obtain from five different spray tip arrangements across a wide range in travel speeds. An application rate of 50 gallons per acre is optimal, higher rates will increase contact fatty alcohol usage and lower rates will reduce spray effectiveness (maintain at least 45 gal/ac).

Table. 10. Spray application rate with four different spray tip arrangements over a range in travel speeds, calculated based on 48 in. row spacing and 20 psi spray pressure.

	Spray tip arrangement (3 tips per row)			
Speed (mph)	TG-3 (2) TG-5	TG-3 (2) TG-4	TG-2 (2) TG-4	TG-2 (2) TG-3
	gallons per acre			
2.0	93.4	84.8	68.7	60.0
2.2	84.9	77.1	62.4	54.6
2.4	77.9	70.6	57.2	**50.0**
2.6	71.9	65.2	**52.8**	46.2
2.8	66.7	60.5	**49.1**	42.9
3.0	62.3	56.5	45.8	40.0
3.2	58.4	**53.0**	42.9	37.5
3.4	55.0	**49.9**	40.4	35.3
3.6	**51.9**	47.1	38.2	33.3
3.8	**49.2**	44.6	36.1	31.6
4.0	46.7	42.4	34.3	30.0
4.2	44.5	40.4	32.7	28.6
4.4	42.5	38.5	31.2	27.3
4.6	40.6	36.9	29.9	26.1
4.8	38.9	35.3	28.6	25.0
5.0	37.4	33.9	27.5	24.0

Calibration of a sprayer using the 1/128th acre method is relatively easy. Using this method for a row spacing of 48 inches, the travel time with a tractor in the field is recorded for a distance of 85 ft. Collect water from the spray tips at operating pressure for the length of travel time (85 ft). The amount of water collected from all three nozzles of one row is equal to the spray application rate in gallons per acre. The travel time for the 85 ft calibration distance increases from 16 seconds for 3.6 mph to 22 seconds for 2.6 mph. Additional information on using the 1/128th acre method of calibration and determining travel speeds may be found in this production guide.

Reduced MH and MH-Free Sucker Control Test

Results from a sucker control test conducted at the Southern Piedmont Center in 2007 are presented in Table 11. This set of treatments was part of a larger test conducted to evaluate reduce MH and MH-free sucker control treatments. Results are expressed in terms of percent sucker control which is calculated based on the weight of sucker compared to a treatment receiving no chemical sucker control (topped-not-suckered). All treatments were applied using 2 TG-3 tips and 1 TG-5 over the center of the row, except treatment nos. 5 and 8. These treatments were applied with 2 TG-2 tips and a TG-6 to direct a greater proportion of the spray material directly over the plant stalk (60% compared to the typical 47% with the TG-3's and 5). Travel speed was reduced slightly to provide for the same application rate (50 GPA) with the two spray tip arrangements. The two treatments with 1.5 gal of MH-30 (2.25 lbs a.i. per ac) provided the poorest sucker control at approximately 30%. The tankmix of 1.5 gal MH-30 and 2 qt/ac of the dinitroaniline, Flupro, significantly improved sucker control to greater than 90%. Similar levels of control were obtained from treatments with reduced rates of MH in combination with Flupro (Trt. nos. 1 and 4). Omitting MH entirely and applying 2 qt/ac of Flupro (Trt. nos. 5 and 6) did not provide satisfactory control when applied once, but when split in two application of 1 qt each (trt. no. 2) did provide excellent control. The third and fourth spray applications in this test were separated by 18 days with the first harvest occurring during this time. No differences were observed between treatments comparing applications using TG3's and a 5 with TG-2's and a 6. Results of the tests reinforce the fact that the tankmix of 1.5 gal MH -30 with 2 qt of a dinitroaniline is the standard for sequential sucker control. The results also show promise with regard to the possibility of reducing the rate of MH when used in conjunction with a dinitroaniline (Trt. nos. 1 and 4). These and similar reduced MH or MH-free treatments need to be evaluated further under a wider range of conditions to ensure their reliability. Reducing or eliminating the systemic control obtained from MH will require greater management to ensure satisfactory results from dinitroanilines. Proper application technique and timing will be critically important to minimize the growth of escape suckers that can occur.

Table 11. Reduced MH and MH Free Sucker Control Test Conducted at the Southern Piedmont Center, Blackstone, Va. 2007.

Trt. No.	Application 1st	2nd	3rd	4th	Percent Sucker Control[1]
1	FA[2] 4%	FA 5%	Flupro 1 qt	MH-30 & Flupro 3 qt and 1 qt	97.9 a
2	FA 4%	FA 5%	Flupro 1 qt	Flupro 1 qt	96.6 a
3	FA 4%	FA 5%	MH-30 & Flupro 1.5 gal and 2 qt		91.5 a
4	FA 4%	FA 5%	Flupro 2 qt	MH-30 1 gal	90.0 a
5	FA 4%	FA 5%	Flupro 2 qt	*(2 TG-2 and 1 TG-6)*	69.4 b
6	FA 4%	FA 5%	Flupro 2 qt		66.9 b
7	FA 4%	FA 5%	MH-30 1.5 gal	*(2 TG-2 and 1 TG-6)*	32.1 c
8	FA 4%	FA 5%	MH-30 1.5 gal		28.0 c

[1]Percent sucker control values followed by the same letter are not significantly different.
[2]FA= contact fatty alcohol (Sucker Plucker was used in this test but other products could be substituted with similar results).

Suggestions for Application of Sucker Control Materials

<table>
<tr><th>Product Type</th><th>When to Apply</th><th>Application Rate</th></tr>
<tr><td>Contacts (fatty alcohols)</td><td>1. 1st appl. at 50% elongated button
2. 2nd appl. 3 to 5 days after 1st appl.
3. Late season application 3 to 4 weeks after MH, if needed</td><td>1st application as a 4% solution or 2 gal in 48 gal of water
2nd application as a 5% solution or 2.5 gal in 47.5 gal of water

C_{10} products are applied at 3 and 4% for the 1st and 2nd applications, respectively</td></tr>
<tr><td colspan="3">Application Procedure
<u>Power Spray</u>
20 psi using 3 solid cone nozzles per row (i.e. 1 TG-5 and 2 TG-3's)
Apply 50 gal of spray material per acre
<u>Hand Application</u>
20 psi max. and ½ to $^{2}/_{3}$ fl oz per plant</td></tr>
<tr><td>Local systemics (flumetralin)</td><td>1. Individual plants at elongated button stage (dropline or jug application)
2. 5 days after 1st contact application
3. Late season application 3 to 4 weeks after MH, if needed</td><td><u>Power Spray</u>
2 qt/a of flumetralin

Apply 50 gal of spray material per acre.

<u>Hand Application</u>
2% solution or 1 gal in 49 gal of water (2.5 fl oz of flumetralin per gal of water). Do not apply more than 30 gal of spray per acre</td></tr>
<tr><td colspan="3">Application Procedure
<u>Power Spray</u>
15 - 20 psi using 3 solid cone nozzles per row (i.e. 1 TG-5 and 2 TG-3's)
<u>Hand Application</u>
coarse spray (20 psi and TG-3 or 5 nozzle) or drench using jugs and apply ½ to $^{2}/_{3}$ fl oz per plant depending on height</td></tr>
</table>

Suggestions for Application of Sucker Control Materials (Cont'd)

Product Type	When to Apply	Application Rate
Systemics (MH)	When used as part of sequential control program - apply 1 week after 2nd contact application.	2.25 to 3.0 lb of MH (1.5 to 2 gal of 1.5 lb/gal product) (1 to 1.33 gal of 2.25 lb/gal product) Apply 40 to 50 gal of spray material per acre.
Application Procedure		
Apply as a coarse spray using 3 solid cone nozzles (i.e. TG-5 and 2 TG-3's). Direct spray toward upper third of the plant.		
Tank mix of MH with flumetralin	When used as part of sequential control program - apply 1 week after 2nd contact application.	2.25 to 3.0 lb MH with 2 qt/A of flumetralin Apply 50 gal of spray material per acre.
Application Procedure		
Apply as coarse spray using 3 solid cone nozzles (i.e. TG-5 and 2 TG-3's) and 20-25 psi.		

CHEMICAL COLORING AGENTS

Ethy-gen and ethephon are products reputed to aid in "coloring" tobacco and reduce the yellowing time during curing. Growers should not expect these products to solve problems such as ripening late maturing tobacco that is over-fertilized.

Ethy-gen is released in the barn during the yellowing stage of the cure. Ethephon is the only approved chemical to use for coloring tobacco in the field. The yellowing obtained from an ethephon application is influenced by weather conditions. Experience has shown that cool, cloudy conditions slow the yellowing rate and coloring may not be uniform. If a producer decides to use ethephon, a few representative test plants should be sprayed and observed for two to four days to determine if desired yellowing can be achieved. If the test plants fail to yellow as desired, further maturing may be needed before the crop should be sprayed. Only physiologically mature leaves remaining on the plant after the second or third priming should be treated. Ethrel (2 lbs per gal) was the original ethephon product labeled as a yellowing agent for tobacco and was followed by Prep and Marture XL (6 lbs per gal). Additional generic products have been labeled in recent years. **The use of other chemicals for this purpose is illegal and could result in severe penalty for the grower.**

Growers should follow manufacturer's suggestions on proper use of these materials.

Guidelines for the Use of Ethephon (6 lbs per gal. products)*

Application method	Rate pts/a	Spray volume	Application directions
Directed spray	$1\frac{1}{3}$	50 to 60 gal/A	Apply with drop nozzles to direct spray to leaves to be harvested. Use coarse spray tips at 35 to 40 psi.
Over-the-top	$1\frac{1}{3}$ to $2\frac{2}{3}$	40 to 60 gal/A	Apply as a fine spray using three spray tips over each row to cover all leaves thoroughly. Use a spray pressure of 40 to 60 psi.

*Read and follow all label directions regarding use rates, application procedures, and worker protection standards (WPS). Growers must comply with label requirements regarding worker notification, restricted-entry interval (REI), and personal protective equipment (PPE).