

4. Producing Healthy Transplants in a Float System

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To produce high-quality tobacco, growers must begin with healthy transplants. An ideal transplant is disease free, hardy enough to survive transplanting shock, and available for transplanting on time. In general, early transplanted tobacco yields more than late-transplanted tobacco. The historical last-frost date for a region is a good guideline for selecting a date for setting out transplants, but the five-day weather forecast is better. In general, tobacco that has been transplanted for several days can tolerate frost better than recently transplanted tobacco.

The greenhouse float-system method produces excellent quality transplants with uniform stem lengths in a very predictable time period. However, the weather does affect production in the greenhouse. For example, cool, cloudy conditions can delay germination. Unseasonably warm temperatures in February and March can increase the rate of plant growth, causing problems with stem and root diseases, particularly if the seeds are planted in the greenhouse too early. Successful transplant production in a greenhouse requires intensive management with great attention to details. Little problems can become big problems very quickly.

Transplant production costs per acre increase when the percentage of usable transplants decreases. Therefore, management practices that improve stands and promote uniform growth decrease production costs. Nearly all management practices affect usability, but these are some of the most important:

1. Consider the materials.

- Analyze the water source and manage alkalinity.
- Select a uniform, high-quality growing medium with a low and well-mixed nutrient charge.
- Consider tray design.
- Use seeds with high germination rates and acceptable pelleting materials.

2. Promote uniform emergence.

- Sow seeds during sunny periods.
- Fill trays uniformly.
- Place seeds uniformly (in the center of the dibble).
- Provide a warm temperature (68 to 70°F at night).
- Reduce spiral rooting.
- Control ants and mice.

3. Promote uniform growth.

- Monitor fertilizer salts in the medium and leach with water from overhead when necessary.
- Continue to analyze water and manage alkalinity when necessary.
- Clip properly.
- Manage insects and diseases.

4. Prevent stand loss.

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

Consider the Materials

Analyze the Water Source and Manage Alkalinity

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

The North Carolina Department of Agriculture and Consumer Services (NCDACS) analyzes water at a cost of \$5 per sample. Growers receive a detailed report about the nutritional suitability of each water sample for transplant production.

Collect a 16-ounce sample from each potential water source. A clean, nonreturnable drink bottle with a screw-on cap makes an excellent sample bottle. Rinse the bottle (but do not use soap) several times and allow the water to run several minutes before collecting the sample. Forms and assistance are available from county Cooperative Extension centers.

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

Select a High-Quality Growing Medium

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

Consider Tray Design

Researchers continue to investigate tray design in relationship to production costs and disease management. A significant factor affecting tray cost to the grower is the cost of fuel. High natural gas prices have increased the cost of manufacturing, while high fuel prices have increased the cost of transportation and delivery.

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

Recently a glazed tray was introduced that has hardened sidewalls within the cell, which are formed by superheating during the

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

Studies conducted in 2004 and 2005 measured the effects of cell density and volume on transplant production (Tables 4-1 and 4-2). Researchers compared four trays differing in cell density and volume filled with three different growing media. They compared the following trays:

1. A glazed 288-cell tray with a cell volume of 15 cubic centimeters and cell density of 122.5 cells per square foot in 2004 and a traditional 288-cell tray with a cell volume of 18 cubic centimeters and cell density of 122.5 cells per square foot in 2005.
2. A shallow, glazed 288-cell tray with a cell volume of 8.6 cubic centimeters and cell density of 122.5 cells per square foot.
3. A traditional 200-cell tray with a cell volume of 27 cubic centimeters and cell density of 85 cells per square foot.
4. A shallow 200-cell tray with a cell volume of 8.6 cubic centimeters and a cell density of 85 cells per square foot.

Results indicate that 200-cell trays produced larger plants than 288-cell trays. However, there were no differences in plant size due to tray depth. Thus, in a float system, cell density is more important than cell depth (root volume) in affecting plant size. These results indicate that shallow trays can be used without reducing transplant quality. There were minor differences in usability among media in 2005. However, there were no interactions between media and tray type in 2004 or 2005. Thus, all of these media would be suitable for shallow trays.

Promote Uniform Emergence

Uniform emergence and growth are necessary to produce a high percentage of usable transplants. Research conducted in 1999 and

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

Treatment	ISM¹ (%)	Spiral Root (%)	Total Plants (%)	Usable Plants (%)	Stem Length (cm)	Stem Diam. (mm)
Trays						
<i>Glazed 288 Traditional (15 cc per cell)</i>	95	3	94	88	6.4	3.0
<i>Glazed 288 Shallow (8.6 cc per cell)</i>	96	4	92	84	6.3	3.0
<i>200 Traditional (27 cc per cell)</i>	96	3	95	90	7.0	3.6
<i>200 Shallow (8.6 cc/cell)</i>	95	3	94	87	7.0	3.8
<i>LSD (0.05)</i>	NS	NS	NS	4	0.3	0.3
Growing Medium						
<i>Carolina Gold</i>	95	3	94	87	6.6	3.3
<i>Carolina Choice</i>	96	4	94	88	6.5	3.4
<i>All Peat, Aggregate Free—Experimental</i>	96	4	93	86	6.8	3.3
<i>LSD (0.05)</i>	NS	NS	NS	NS	NS	NS

¹ ISM = Modified Index of Synchrony, which is a measure of the uniformity of germination. It is calculated as the percentage of the total germination that occurred over a 48-hour period.

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

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

<i>Treatment</i>	<i>Emergence (%)</i>	<i>Total Plants (%)</i>	<i>Usable Plants (%)</i>	<i>Stem Length (cm)</i>	<i>Stem Diam. (mm)</i>
Trays					
<i>288 Traditional (17.5 cc per cell)</i>	94	90	79	4.9	2.5
<i>Glazed 288 Shallow (8.6 cc per cell)</i>	96	91	81	5.9	2.4
<i>200 Traditional (27 cc per cell)</i>	94	91	84	6.2	2.9
<i>200 Shallow (8.6 cc/cell)</i>	94	92	84	6.1	2.9
<i>LSD (0.05)</i>	2	NS	NS	0.4	0.3
Growing Medium					
<i>Carolina Gold</i>	93	87	78	5.7	2.6
<i>Carolina Choice</i>	95	93	84	5.8	2.6
<i>All Peat, Aggregate Free—Experimental</i>	95	93	84	5.9	2.7
<i>LSD (0.05)</i>	2	5	4	NS	NS

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

2000 showed that even a three-day delay in emergence in 25 percent of the seedlings could reduce usability (Table 4-3). The researchers seeded random cells within a tray 3, 5, 7, or 12 days after seeding the rest of the tray. In general, the delayed treatments produced fewer usable seedlings than the initial seeding. These results show the importance of uniform emergence and that clipping will not correct the uneven growth from delayed emergence.

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

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

<i>Treatment</i>	<i>Total Stand at Day 50</i>	<i>Usable Transplants at Day 50</i>
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.

not been shown to speed seedling emergence. However, the use of a premoistened medium decreases the amount of medium that falls through the holes in the bottom of the tray and increases the speed of emergence as compared to a dry medium. Overly wet media do not flow from the hopper box as uniformly as dry media. Be sure the trays are filled uniformly.

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

Manage Spiral Rooting

Spiral roots (aerial roots) can cause significant stand losses. In general, the reduction in the number of usable transplants is about one-half of the percentage of spiral rooting. For example, if 10 percent of the cells in a tray contain spiral roots, a grower can expect the number of usable transplants to be reduced by 5 percent. Some of the conditions that may induce spiral rooting can occur when seeds are sown.

Causes of spiral rooting. Researchers have found that spiral rooting results from complex interactions among the variety sown, pelleting material, growing medium, and environment. For example, differences in spiral rooting among varieties are common. We do not know if these differences are genetic, a coincidence involving the time of germination and an environment favorable for spiral root development, the seed pelleting material, or some combination of these factors. Tests have shown differences in spiral rooting when different companies coated the same seed lot of one variety. Differences in spiral rooting have also been observed when the same company coated seeds of the same variety. The greenhouse environment is also a factor. We commonly see differences in spiral rooting levels when tests with the same seed and growing medium are conducted by specialists in Virginia, North Carolina, and South Carolina.

Differences in spiral root incidence have also been observed

between brands of growing medium. However, a brand of growing medium may cause more spiral roots than others one year, but not the next.

Recent observations suggest that pellets harden after repeated cycles of drying and rewetting, similar to the conditions that occur when temperature and humidity in the greenhouse change from day to night. The hard pellet then becomes a barrier between an emerging root and the growing medium, preventing normal root penetration. Research in North Carolina that has found increased spiral rooting under hot and sunny conditions supports these observations. Thus, spiral roots may occur when the greenhouse environment contributes to the growing medium being too wet, as well as when the surface of the medium is too dry. Therefore, seeding date will not consistently reduce spiral rooting because the set of known “good” environmental conditions is too narrow.

Primed seeds. Priming is a seed treatment that begins the germination process in a seed company’s laboratory. After the early stages of germination occur from exposure to warm temperature, darkness, water, and then light, the seeds are dried. This treatment produces seeds that are at the same stage of germination when purchased by the grower, and seedlings emerge quickly and uniformly. However, research has shown that priming sometimes improves the rate of seedling emergence (by one to two days) but seldom improves the uniformity of emergence. There is also considerable variation in priming response among varieties tested and among seed lots within a variety. Therefore, the decision to prime seeds should be made by the seed company, based on pretesting of individual seed lots, rather than by the grower (unless the grower intends to cover seeds with growing medium to prevent spiral rooting).

Provide a Warm Temperature

The ideal germination temperature for tobacco seeds is approximately 68°F at night and 86°F during the day. Fuel use decreases 15 percent for every 5-degree reduction in temperature. Therefore, after maximum seedling emergence is obtained, nighttime temperatures should be reduced to a range of 55 to 60°F to conserve fuel usage. Daytime temperatures of 80 to 85°F are adequate for normal growth. Heat injury (browning of leaves or seedling death) has been observed when air temperatures inside the structure exceed 110°F.

Promote Uniform Growth

Monitor and Manage Fertilizer Salts in the Growing Medium

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

High temperatures, low humidity, and excessive air movement promote water evaporation from the surface of the growing medium, which results in the 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 4-1). Fertilizer salts levels in the upper ½-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.

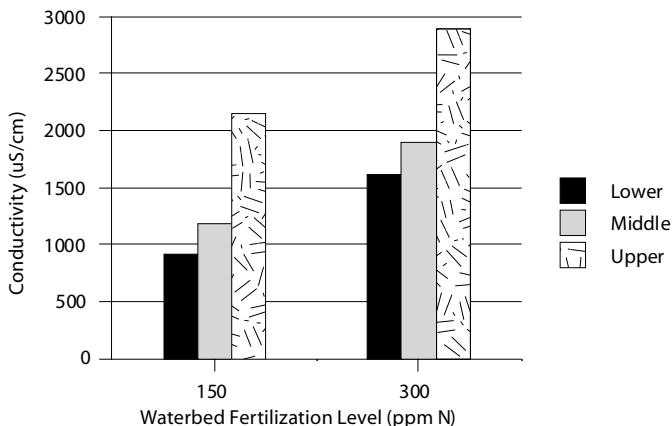
Electrical conductivity is a commonly used indicator of fertilizer salts levels in media and water. Pocket-sized conductivity meters are available for a reasonable price from many farm supply dealerships. When properly calibrated, these meters are very helpful in a salts-monitoring program for float 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 ½-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 2 to 3 minutes before measuring the conductivity. Normal levels range from 500 to 1,000 microseimens (0.5 to 1 millimhos). Readings of 1,000 to 1,500 microseimens (1 to 1.5 millimhos) are moderately high, and readings above 1,500 microseimens are very high. Apply water from overhead to leach and dilute salts when: (1) conductivity readings are above 1,000 microseimens and plants are pale or stop growing; or (2) conductivity readings are 1,500 microseimens or above.

Fertilize Properly

Growers with fertilizer injection systems have been successful in using a constant application rate of 100 parts per million (ppm) nitrogen

Figure 4-1. Conductivity of a soilless medium at two fertilization levels and at three depths in the cell.



from 20-10-20, 16-4-16, 16-5-16, 15-5-15, or similar ratio fertilizers. For noninjected systems, fertilizer can be added to the water in two steps. Research has shown that excellent transplants can be obtained from an initial application of fertilizer to supply 75 to 100 ppm nitrogen within seven days after seeding plus a second application to supply 75 to 100 ppm nitrogen four weeks later. Use a complete fertilizer (with 2-1-2, 3-1-3, or 4-1-4 ratios) for the first application. The same fertilizer or ammonium nitrate can be used for the second application. Higher application rates cause tender, succulent seedlings that are more susceptible to diseases. Also, high application rates promote fertilizer salts injury to seedlings as noted above. If high fertilizer salts levels are detected during the first four weeks after seeding (>1,000 microseimens in the medium from the upper ½-inch of the cell), apply water uniformly from over-top to reduce fertilizer salts levels.

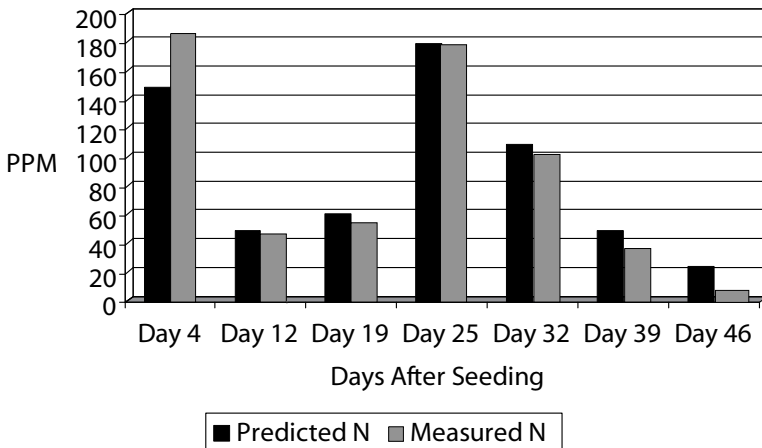
Monitoring waterbed fertility levels. Pocket-sized conductivity meters can be used to monitor fertility levels in waterbeds. Most fertilizer labels contain a chart that provides the expected conductivity level for the initial fertilizer concentration, usually expressed as nitrogen concentration in ppm. Conductivity is useful in measuring the accuracy of fertilizer injectors and how well the fertilizer is mixed throughout the waterbed. Conductivity measurements can also provide a rough estimate of the general fertility status in a waterbed

throughout the growing season. It is important to understand that while the chart lists nitrogen concentration, the meter is measuring total conductivity from all salts (nutrients). Therefore, as the season progresses and plants adsorb nutrients from the waterbed at different rates (and water levels fluctuate), the relationship between conductivity and nitrogen concentration becomes less dependable (Figure 4-2). Therefore, collecting a water sample for analysis by the NCDA&CS (or another laboratory) is the only way to get an accurate measure of the concentrations of all nutrients in the waterbed.

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 conducted in 1994 showed reduced seedling growth when more than half of the nitrogen in a fertilizer was provided from urea, as compared to all of the nitrogen being supplied as nitrate and ammonium. Similar results have been observed at the University of Kentucky, where Bob Pearce suggests that reductions in plant growth may be a result of nitrite toxicity. Nitrite is an intermediate nitrogen form that occurs when ammonium converts to nitrate. Nitrite can accumulate to levels high enough to cause plant injury when high levels of ammonium are present.

Figure 4-2. A comparison of predicted (based on conductivity) and measured nitrogen concentrations in a float bed, 2002.



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

Phosphorus. Research at Clemson University has shown the need to limit phosphorus concentrations to 35 to 50 ppm in the waterbed. Applying excess phosphorus causes spindly transplants and leaves more phosphorus in the waterbed for disposal after transplant production. Therefore, 20-10-20 and 20-9-20 are better choices than 20-20-20 fertilizer. Other fertilizers, such as 15-5-15, and 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. However, over-application of acidic fertilizers in low-alkalinity water can reduce the solution pH to less than 4.0, which damages roots (if plant roots grow into the waterbed).

Sulfur. A sulfur deficiency is occasionally observed in float systems when the medium was not supplemented with magnesium sulfate (Epsom salts) or calcium sulfate (gypsum) and sulfur was not provided by the fertilization program. The major media marketed for tobacco should contain sulfur. Also, some fertilizers such as 16-5-16 contain sulfur. If the sulfur content in a medium is questionable, the fertilizer used does not contain sulfur, or a sulfur deficiency is observed, add Epsom salts to the waterbed at a rate of 4 ounces per 100 gallons of water.

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

Organic fertilization. In recent years, some growers have contracted to grow tobacco organically. Thus far, it has been acceptable to produce transplants with the water-soluble fertilizers typically used in float systems. However, growers may be required to use organic fertilizers during transplant production for USDA organic certification

in the future. Studies were conducted in 2002 and 2003 to compare seedling production when using bat manure (8-4-1) and Peruvian seabird guano (13-8-2) to seedling production when using the standard water-soluble fertilizer 16-5-16 (Table 4-4).

Results show that seabird guano is a better choice than bat manure when both are applied at the normal rate. Only 33 percent of the nitrogen in bat manure is in a plant-available form, which resulted in small, nitrogen-deficient seedlings when used at the normal rate in 2002 and 2003. In 2003, tripling the bat manure rate to compensate for reduced availability resulted in seedlings comparable to the seabird guano. However, a 3x rate of bat guano is very expensive.

In 2003, both organic products produced smaller seedlings and a lower percentage of usable seedlings than 16-5-16. In 2002, the seabird guano and 16-5-16 produced similar percentages of usable transplants. Based on these results, the Peruvian seabird guano seems to be a better choice than bat manure for organic seedling production. Growers using seabird guano should monitor alkalinity levels in the waterbed closely and correct when necessary.

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

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

Where:

Fertilizer added per 100 gallons = amount of fertilizer to add to each 100 gallons of water in the waterbed;

Concentration = desired concentration in parts per million;

% = concentration of the nutrient in the fertilizer.

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

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

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

<i>Fertilizer</i>	<i>Stem Length (cm/plant)</i>		<i>Usable Transplants (%)</i>	
	<i>2002</i>	<i>2003</i>	<i>2002</i>	<i>2003</i>
<i>16-5-16</i>	8.7	5	73	88
<i>Bat Manure (8-4-1)</i>	2.6	1	0	0
<i>Peruvian Seabird Guano (13-8-2)</i>	6.8	3	77	72
<i>Bat Manure (8-4-1) at a 3× rate</i>	—	3	—	84

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 3 to 5 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 North Carolina 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 collectg residue with reel mowers to accomplish this.

Research conducted by David Reed at Virginia Tech showed that the severity of clipping affects stem length at the time of transplanting. For example, severe clipping (0.5 inch above the bud) decreased stem length but did not increase stem diameter as compared to normal clipping (1.5 inches above the bud). Therefore, there is no advantage in 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 to set the blade height at 1 to 1.5 inches above the bud. This procedure provides the best balance of uniformity, stem length, and disease management.