Chapter 10
Plasticulture in the Midwest

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Strawberry plasticulture is an annual hill training system in which freshly dug bare-root plants or plugs (transplants started from runner tips) are planted in late summer to early fall, depending on the climate. Plants are set out in double rows at densities of 15,000 to 17,500 plants per acre. Special equipment is needed to make the 8-inch-deep raised beds that are customarily fumigated with methyl bromide, Telone C-35, or metam sodium and covered with black plastic mulch (Figure 10-1).

Strawberry plasticulture in northern states is still quite limited, but matted-row growers in the Midwest and Mid-Atlantic states are taking a closer look at this production system because it has several advantages, including easier picking and earlier harvesting. Plasticulture berries can be harvested in seven to eight months after planting compared to 12 months for matted-row production.

Strawberries grown using the plasticulture system, however, must be intensively managed. Furthermore, daily production and pest management decisions can have a much greater effect on yields and profits than decisions made for matted-row systems. With a plasticulture system, there is considerably less margin for error in regard to soil treatments, timing, pest management, frost and freeze strategies, and marketing.

The strawberry plasticulture production system performs best in the milder areas of the Southeast, Northeast, and Midwest where temperatures rarely fall below 0°F (USDA Climate Zones 7 and higher). This isn't surprising: The plasticulture system evolved in the southern states and California.

But growers in USDA Climate Zone 6 (and warmer sites in Climate Zone 5), where temperatures can drop to -10°F, are achieving success with annual plantings of the Chandler variety using the plasticulture system. This zone includes the colder areas of North Carolina (the foothills and mountains) and similar climates in eastern Maryland, Delaware, and southern New Jersey. Similarly, southern Illinois, which was once called *Egypt* in Abraham Lincoln's time, is going to be better suited to strawberry plasticulture than northern Illinois and colder areas of the Midwest.

Figure 10-1. Sandy loam and clay loam soils are ideal for building and shaping the 8-inch raised beds that are a critical component to success in the strawberry plasticulture system. The raised beds are 8-inches high and 28- to 30-inches wide at the base. These beds are fumigated at least three weeks prior to transplanting, depending on the fumigant. As the fumigant is injected (shank injected), the beds are immediately tarped with an embossed 1.25 mil black plastic mulch film that can be stretched by the mulch-laying/fumigation unit to give an extra tight fit over the bed. The black plastic film needs to be in direct contact with the soil (for maximum soil warming to occur in the late fall and winter months). If there are air pockets between the film and the soil, the black plastic will actually serve to cool the soil, and plant top-growth and root development will be significantly reduced.

Based on research completed at North Carolina State University, strawberry growers need to achieve yields of at least 1 pound of berries per plant, or 15,000 pounds per acre, to make a profit using plasticulture (Safley and Poling, 2004). To achieve these yields in Zone 6, growers need to know the recommended cultivars and practices to use for successful production.

To meet that need, this publication provides an overview of the factors that growers in USDA Zone 6 should consider before deciding to use the plasticulture system for growing strawberries. It also describes recommended practices for the different stages of plasticulture production, from preplanting through harvest. Refer to *Producing and Marketing Strawberries for Direct Markets* by Safley and Poling (Publication No. AG-645, Raleigh: North Carolina Cooperative Extension, North Carolina State University) for in-depth information about the cost and returns of growing, harvesting, and marketing strawberries using plasticulture.

Preliminary Considerations Prior to Going into Plasticulture

Before deciding to use the plasticulture system for strawberries, a grower should carefully consider these factors:

- Site
- Soil
- Equipment
- Plant materials and sources
- Production challenges
- Production time.

Site

Attention to the specific site selection factors listed here will improve the likelihood of success in Zone 6.

Windbreaks. The most reliably productive strawberry plasticulture sites are almost always those with a wooded area or a windbreak on the north or northwest side of the field.

Row Orientation. A north-to-south orientation is recommended for more uniform plant stands and ripening. However, if the field is almost flat, facilitating soil drainage is the most important factor.

Crop Rotation. It is best to rotate strawberry field sites as often as possible, but the general practice in most areas is to crop strawberries continuously on the same land because of existing irrigation lines and market location. Avoid rotations with crops treated with herbicides or plant growth regulators (or a combination of these) that could carryover and cause crop losses in strawberries. Read all pesticide labels carefully for rotational restrictions.

Wildlife. Most strawberry plasticulture sites require protection from deer within a month or two of planting.

Soil

Soil Content. Strawberries grow and produce satisfactorily in a wide range of soil types, but sandy loam and sandy clay-loam soils are ideal for building and shaping the 8-inch-deep raised beds that are critical to the success of the strawberry plasticulture system. Soils with a high clay content or those that are rocky or very stony are more difficult for bedding, fumigation, and plastic-mulch operations.

As a general rule, growers should consider using plug plants on soils with a high clay content or soils that are rocky or very stony rather than bare-root freshly dug plants, which require hand transplanting. Sandy soils will require more careful irrigation and nutrient management.

Soil pH. Optimal strawberry production requires a favorable root environment and the availability of essential nutrients. Soil pH is a key factor in maintaining a favorable root environment. Soils with a pH between 6.0 to 6.4 promote the best growth. A soil test can indicate how much lime is needed.

Low pH is one of the most frequent problems identified on soil samples in Zone 6. Because the problem cannot be corrected after planting and low calcium (Ca) usually accompanies a low soil pH, testing and liming the soil as needed is especially important.

Soil Moisture. For all soil types and strawberry-growing regions in the Midwest, a drip irrigation system is required to meet the moisture requirements of the crop. See the section on *Equipment* for more details.

Soil Erosion and Surface Water Management. Although raised beds encourage water drainage within the soil, plasticulture growers frequently encounter problems with getting rid of excess surface water. Because 50 percent of a plasticulture strawberry field is covered with an impermeable plastic film, the field should have enough slope that surface water drains uniformly and gently from the field after periods of heavy precipitation, without causing erosion or leaving puddles.

On fields with more than a 2 percent slope (a 2-foot drop in 100 feet), continuous overhead sprinkling for freshly dug plant establishment may cause severe soil erosion. This is why it is often a good idea to broadcast annual ryegrass at a rate of approximately 50 pounds per acre over the entire field the same day you finish fumigating (before planting holes are punched). Ryegrass will reduce soil washing in the aisles after heavy rains or irrigation for establishing freshly dug plants on sloping terrain. Even in colder northern growing areas, the ryegrass should be killed or stunted by an application of post-emergence grass herbicide when it is about 6- to 8-inches tall (Figure 10-2).

Figure 10-2. Annual ryegrass should be killed or stunted by an application of post-emergence herbicide when it is about 6- to 8-inches tall and before row covers are applied for winter protection.

Equipment

Specialty equipment is needed for successful strawberry plasticulture production. This equipment includes:

- Equipment for bed-shaping, plastic-laying, and fumigation.
- An overhead sprinkler irrigation system.
- A drip irrigation system to meet the moisture requirements of the crop.

Shaping the Beds

New growers should consider hiring a contractor who has the necessary equipment and knows how to use it. Custom applicators can form beds, inject fumigant, apply plastic, and lay trickle tubes in one operation. Where custom services are unavailable for shaping beds, fumigating the soil, and laying plastic, you must either purchase equipment or make arrangements to lease it.

Overhead Sprinkler Irrigation

Strawberry plasticulture requires overhead sprinkler irrigation for establishing freshly dug bare-root plants, protecting blossoms from cold injury, and for evaporative cooling during occasional spring heat waves that cause open blossoms to abort. It is prudent to plan for at least 12 frost-and-freeze episodes per season.

The water requirement for an overhead sprinkler irrigation system is usually estimated on the basis of three consecutive frost or freeze nights. For example, 5.4 acre-inches of water (27,152 gallons equal 1 acre-inch) would be needed for sprinkling at the rate of 0.18 inch per hour (for control down to 24°F), for 10 continuous hours each night over three nights. Or, 1.8 inch per night (10 hours times 0.18 inch) for three nights equals 5.4 acre-inches.

An irrigation pond would need to hold about 150,000 gallons of water for each acre of plasticulture production under these conditions (5.4 inches times 27,152 gallons per acre-inch equals 146,620 gallons).

Several factors should be considered before installing an irrigation system:

- **Water supply.** Water may come from wells, ponds, lakes, and municipal lines. An irrigation pond would need to hold about 150,000 gallons of water for each acre of plasticulture production to provide protection on three consecutive frost or freeze nights.
- **Pumping capacity.** A pumping capacity of as much as 90 gallons per minute (gpm) or 0.2 inch per hour is recommended for severe frost and freeze conditions.

- **Pump.** An electric pump is recommended for reliability if you have a reliable electric power service.
- **Sprinkler type.** Low-impact sprinklers are preferred.
- **Sprinkler spacing.** A 40-foot by 40-foot triangular spacing will greatly improve the sprinkling distribution pattern under higher winds as compared to a conventional 60-foot by 60-foot spacing.

Drip Irrigation

The deep 8- and 10-inch beds require drip irrigation because capillary movement of water is poor. Drip irrigation provides the most efficient use of water and fertilizer. Many deep wells are fairly clean and require only a screen filter to remove particles. However, the presence of precipitates or other contaminants in the water should be determined by a water-quality test before considering the well for a drip system. Any surface water source, such as a stream, pond, pit, or river, will contain bacteria, algae, or other aquatic life, and sand or special filters are therefore a necessity.

For strawberries, a drip tape is used to wet a continuous strip along the row. A 12-inch emitter spacing is recommended for sandy loam and clay soils. For coarse sands, 8-inch emitter spacing is recommended. Drip emitter discharge rates are generally expressed in gallons per minute (gpm) per 100 feet of length for the selected emitter spacing. A common tape selection for plasticulture strawberries on sandy loam or clay soils uses 0.40 gpm emitters (24 gallons per hour, gph, per 100 feet). To determine field water requirements in gpm per acre, simply multiply 24 gph times 87.12 (the number of 100-foot row units per acre on 5-foot bed spacing) and divide by 60, which yields 35 gpm.

Because strawberries grown on plastic mulch are considered annuals and are grown for only one season, thin, disposable drip tape (4 to 8 mils thick) is commonly used. Once a drip irrigation system is installed, the crop can be fertilized using the drip system (fertigation). The drip system also can be used to establish plug transplants in the late summer, but some overhead sprinkler irrigation should still be applied for the first two to three days after transplanting (see the section on ordering and handling tips and plugs).

Plant Materials and Sources

Growers in Zone 6 should use a cultivar recommended for colder climates and choose planting material (freshly dug plants or plugs) that best suits their growing conditions and operation. Planting material should be obtained from reliable sources that provide disease-free material.

Cultivars

These cultivars are recommended:

Chandler

This cultivar is the "old reliable" for northern plasticulture. It is possible to grow and successfully market two or three different varieties for strawberry plasticulture in the Southeast to extend the harvest season over a six-week period. However, growers in Zone 6, including southern Illinois and milder sections of the Midwest, should concentrate on planting plug plants of Chandler.

Chandler plugs are being grown by the North Carolina State University research team at an elevation of nearly 3,000 feet in western North Carolina at one of the coldest locations in the state (Laurel Springs). This demonstrates how well adapted this cultivar is to a Zone 6 region (-10°F to 0°F). In the colder areas of Virginia, several matted-row cultivars have been evaluated by Professor Emeritus Charles O'Dell at Virginia Polytechnic Institute and State University. Chandler continues to be the most reliable producer in the plasticulture system for colder areas.

Sweet Charlie

Sweet Charlie is an early ripening strawberry adapted to the mid-Atlantic and southern United States and has a large orange-red fruit color and is moderately firm. Easy to harvest. Good flavor. Flowers early. Tolerant to anthracnose. Yields are about 1/3 lower than Chandler. Patented by the University of Florida.

Darselect

Plasticulture trials have been conducted in Ohio with both dormant frozen plants and plug plants of Darselect. This cultivar was introduced by

Darbonne, a private French breeding-program company. It is reported to be a highly productive, widely adapted variety for plasticulture, and it has been rated very highly for flavor and firmness. Based on recent reports, its fruiting season will be comparable to Chandler (early midseason to midseason).

Ovation

Trials of the cultivar Ovation will be included in the 2005-2006 Mountain Trials for North Carolina. According to USDA trials, Ovation may be well adapted to plasticulture, but further evaluation is needed. It is a late-midseason, disease-resistant variety. According to the USDA, the plant is vigorous, resistant to five strains of red stele, and shows good tolerance to foliage diseases.

Plugs vs. Freshly Dug Plants

Freshly dugs are not usually available until the final week of September, and this is too late for transplanting in northern regions. However, if good quality freshly dugs can be obtained in the third week of September, growers in warmer sections of Zone 6 may wish to evaluate freshly dugs from the standpoint of their relative cost savings and the possibility of enjoying a harvest season that is not quite so concentrated in picking.

Plant Source

The success of a strawberry plasticulture planting, in large part, depends on the health and vigor of the runner tips used for plug propagation. Purchase your runner tips from a reputable supplier. Runner tips must be true-to-variety and free of insects, diseases, nematodes, and viruses.

If you are purchasing plugs from a commercial source, be sure to verify that their runner tips came from a reputable supplier. The Web site **www.ncstrawberry.org** (maintained by the North Carolina Strawberry Association, Inc.) keeps a current listing of U.S. and Canadian plant sources of Chandler, and important details about their respective propagation programs.

Production Challenges Unique to Plasticulture

As noted in the introduction to this publication, decisions made throughout production can make a big impact on the success of plasticulture strawberries. In particular, the system requires close attention to plant size, density, and weather conditions.

Plant Size

Controlling plant size is a very important objective in the plasticulture system regardless of the location. One of the most important influences on plant size and, ultimately, fruit quality is planting date. Select a planting week for your area that will result in the development of four branch crowns, in addition to the main crown, by harvest (Figure 10-3). Four branch crowns are needed to produce a desirable number of berries per plant (around 35 to 40).

But do not plant so early that you end up producing six or more branch crowns per plant. Plants with six or more branch crowns can produce so many blossoms that fruit size will be depressed to the point where both harvesting and marketing the small berries will be a problem.

Plants that are transplanted late will have inadequate cropping potential due to lower branch crown production. Thus, plant density, planting date, and weather conditions must be considered.

Figure 10-3. Strawberry plant with four branch crowns (branch crowns removed) in addition to the main crown. The development of four branch crowns is needed by late winter and before bloom in order to produce a desirable number of berries per plant.

Plant Density

Based on trials with Chandler in western North Carolina (USDA Plant Hardiness Zone 6), plants should be spaced at least 14 inches within each row for a double-row plant bed on 5-foot center. A 14-inch within-row spacing will require 15,000 plants per acre; it is normal to have a 12-inch spacing between the double-rows of plants for standard width plastic mulch beds (28 to 30 inches wide on the top).

Optimum plug planting dates for Chandler in western North Carolina are the first week in September for high elevations and the second week in September for lower elevations. Based on these planting dates, growers in Zone 6 may wish to evaluate planting right around Labor Day, as this has turned out to be the best planting time in North Carolina's coldest mountain areas.

Growers in warmer areas of Zone 6, such as southern Illinois, may find that a suitable time for planting is during the second week of September. If you find that you are producing more than two to three runners per plant in an average fall, this is probably a good indication that you are planting too early.

Warm Fall Conditions

Other factors besides the planting date have an important influence on the final number of branch crowns produced. Fall weather conditions following planting in early to mid-September can play a very important role in determining ultimate plant size. Fall temperatures may be so warm as to produce excessive plant size by harvest (more than six branch crowns).

In North Carolina, growers, who are especially interested in optimizing fruit size and shape, will purposely set out a portion of their crop several days to one week later than recommended for their area in case of an unseasonably warm fall. By planting slightly later in an unseasonably warm fall, you will encounter fewer problems with plants producing runners.

Chandler plugs set at the normal planting date may produce two to three runners per plant in a warm fall, and removing these runners can involve a significant labor expense. In northern plasticulture regions, such as southern Illinois, it may be better to delay the winter row-cover application until late November or early December if you are experiencing an unusually warm fall season.

Cool Fall Conditions

If fall temperatures are cooler than usual, you may encounter difficulties in achieving adequate plant size. Plants that end up developing only two or three branch crowns may have a cropping potential of less than 1 pound per plant. If the fall is unseasonably cool, row covers should be applied earlier to enhance plant growth and branch crown formation. In our coldest regions in western North Carolina, the earliest that row covers would be applied is in the last week of October (around Halloween).

Getting Started in Plasticulture

Plasticulture Production Schedule

Growing strawberries with the plasticulture system is a year-round activity. Just as berries are harvested in the spring, supplies must be ordered for the coming year so the beds can be prepared in late summer. These activities can be organized into the following stages of production:

- Preplanting
- Planting
- Postplanting
- Dormancy
- Preharvest
- Harvest
- Postharvest.

Table 10-1 provides an overview of production by month for Zone 6. A successful harvest depends on the decisions made during production, and timing is essential for success. As noted under *Production Challenges Unique to Plasticulture*, a bountiful harvest depends on plant size and density, which are directly related to the tasks completed during the preplanting and planting stages.

Table 10-1. Plasticulture Strawberry Calendar for USDA Climate Zone 6.

Stage	Month	Activities
DORMANCY	January	Begin a leaf sanitation schedule in late January to early February. Remove dead foliage. If possible, delay this procedure until after the period of greatest likelihood of windborne freeze(s) in January as the older foliage surrounding the crown can provide a beneficial mulching effect. Snap off old leaf petioles at their base. Remove any unwanted runners and weeds.
	February	Leaf sanitation must be completed before the onset of new growth from the crown.
PREHARVEST	February	When new growth emerges from the crowns in mid February to early March, roll back the row covers. Leave row covers in the field in case they are needed for a frost or freeze. After new growth begins, pull up side crowns that are caught beneath the mulch. Remove weeds in the planted holes. Hook up drip irrigation within a week or two after new growth has started. Make the first nitrogen fertilizer injection. Check out the overhead irrigation system to be sure it is ready for use when temperatures fall and row covers become impractical as plants grow.
	March	Main blossoming period begins 4 to 5 weeks after new leaf growth starts and continues for a month. Inspect plants for botrytis and anthracnose. Begin a control program if needed. Stay alert for conditions that favor frost formation at the ground level. Apply overhead sprinkling for frost protection when row covers become impractical. Maintain a weather journal for future reference. Scout for weeds until harvest.
	April	Make sure a farm liability insurance policy is in effect for pick-your-own and fruit stand operations.

Table 10-1 (continued). Plasticulture Strawberry Calendar for USDA Climate Zone 6.

Stage	Month	Activities
HARVEST	April	Harvest begins 9 weeks after the first new growth emerges and continues until about 12 weeks after the new growth emerges.
	May	Order tips and plugs for the next growing season by the first of May. Peak harvest usually occurs around Mother's Day.
POSTHARVEST	June	Destroy plants when harvest ends. Incorporate lime when existing beds are broken down.
PREPLANTING	July	Begin soil preparations. Irrigate overhead to soften soil as needed. Subsoil completely.
	August	Have fumigant cylinders delivered by early August. Check fumigation rig safety. Cut tips for rooting plugs in early August if you are rooting your own. Stick pre-ordered tips or cut tips by mid-August. Broadcast N-P-K fertilizer and disk it into the soil by mid-August. Form and fumigate beds. Lay plastic. Install drip tape.
	September	Inject mefenoxam through the drip system a week before planting if the site has a history of Phytophthora root rot.
PLANTING/ POSTPLANTING	September	Transplant and irrigate plugs during the second or third week of September. Put up electric fences for deer protection.
	October	Check plants carefully for mites three to four weeks after transplanting. Apply miticide if needed before laying down row covers for late fall and early winter. Check for signs of botrytis crown rot when fall temperatures are warm. Begin a fertilization program now if fertilizers were not applied in the preplant stage.

Table 10-1 (continued). Plasticulture Strawberry Calendar for USDA Climate Zone 6.

Stage	Month	Activities
DORMANCY	November	Lay a row covering down five to six weeks after transplanting if planting was delayed by one or two weeks, if plants are small, or if temperatures are unseasonably cool. Otherwise, lay down row covering in late November or early to mid-December so plants will accumulate greater winter hardiness. If a row covering is used early in November, stunt the annual ryegrass in the aisles with a post-emergent herbicide before the covers are applied. Check leaves for presence of spider mites and aphids. Take control steps as needed.
	December	Remove runners as needed beginning four weeks after transplanting to create 7- to 8-inch diameter plants by mid-December with one or two branch crowns and eight to 10 leaves.

Preplanting Activities

Ensure Fertility: Test the Soil

Complete a soil test several months before planting to determine how much dolomitic lime is needed to raise the soil pH and how much potash (K_20) fertilizer to apply before bedding. If a soil test was not taken prior to shaping the beds, use these standard recommendations: Apply 60 pounds nitrogen (N) per acre, 60 pounds phosphate (P_2O_5) per acre, and 120 pounds potash (K_20) per acre. Broadcast these fertilizers and lightly incorporate before bedding and fumigation.

Ammonium nitrate is recommended for the preplanting N application. A broadcast application of 175 pounds per acre of ammonium nitrate will deliver 60 pounds of nitrogen per acre. In general, a P_2O_5 application of 60 pounds per acre should be incorporated even on soil with a high P index. However, on soils that have ultra high levels of phosphorus (typically areas where large amounts of poultry manure have been applied), this application can be deleted. A prebedding broadcast application of 120 pounds triple superphosphate (50 percent) can supply 60 pounds of P_2O_5 per acre.

Soil testing also determines the need for potash (K_20). Potassium sulfate is a very good source of K_20 for strawberries (50 to 53 percent), and it provides some sulfur as well (18 percent). If the soil test recommends 60 pounds K_20 per acre, then a broadcast application of 120 pounds of potassium sulfate fertilizer (50 percent K_20) can be applied to meet the crop's potash requirement. Other nutrients can be injected as called for (preferably as the result of tissue testing) through the drip system.

Shape the Beds

Avoid using a vegetable bed-maker. Instead, stick with the bed-making equipment that is specifically designed for deep strawberry plasticulture beds. A deep bed will produce higher yields and fruit with less soil splash. The eight-inch deep beds mulched in plastic are typically 30 to 32 inches wide at the

base and 28 to 30 inches wide on top. Beds are slightly crowned so water will run off and not rest on the plastic. For example, a bed with a 28- to 30-inch top should slope from the center to the edge with a drop of 1.25 inches. Bed centers are usually 5 feet, and **60-inch-wide plastic film is recommended** (54-inch rolls are not satisfactory).

Most machines have some specific advantages, and it is worthwhile to investigate these differences. Almost all of the machines sold will form the bed, fumigate, lay plastic mulch, and install drip tape in one operation. In general, the single-row bed-making and plastic-laying machines are appropriate for most strawberry operations. Be sure that enough soil is pulled up so that the bed has good, sharp corners and no depression in the center (it is not usually possible to get these sharp corners on clay soils).

You may find it beneficial to pre-bed the rows to make sure that enough soil will be pulled up for the bed-shaper — the same disk hillers used for making tobacco beds work nicely for strawberry pre-bedding. The extra pains involved in getting your land just right for forming beds, laying plastic, and fumigating will pay off in better plant growth in the fall and winter season and higher yields in the spring.

Install Plastic Mulch

Excellent strawberry beds have the plastic mulch in direct contact with the soil beneath. If there are air pockets beneath the plastic, plant growth will be slow in the fall and winter. Heat from the black plastic will not be conducted into the soil if there are air pockets — in fact, the black plastic will have a cooling effect if it is not in good contact with the soil beneath.

Use embossed 1-mil to 1.25-mil black plastic mulch for strawberry plasticulture production. On 5-foot row centers there are 8,712 linear feet of row per acre, so you will need about 3.5 rolls (2,400 feet) of plastic mulch per acre. For 6-foot centers, three rolls of plastic mulch will be required per acre. It is important that the plastic fit tightly on the bed and that the edge of the plastic, or the tuck, be held firmly in the soil. These measures reduce the chance of wind getting under the plastic and causing it to blow off or float up and down, which injures plants.

Install Drip Tubing

Install drip tubing with the orifices facing upwards. The tubing is typically buried 1 or 2 inches deep in the bed center. During installation, several workers should be watching to ensure that the tubing maintains its orifice-upwards orientation, to assist if the tubing becomes tangled in the injector, and to signal when the drip tape reel is empty. Tubing ends should be closed off by kinking or knotting until the tubes are hooked up to the system. Growers have the option of using only overhead sprinklers in the fall, but the drip system should be functional by late winter.

Fumigate

New land that has been subject to good crop rotations and best management practices (such as cover cropping and good drainage strategies) can, under optimum conditions, generate yields that are 85 to 95 percent of the yields in fumigated soil. Weed control, however, can be a serious problem. Strawberry plasticulture production on the same site year after year is not advisable without preplant fumigation because of potential weed and disease problems.

Schedule fumigation far enough in advance to allow for plant-back restrictions for the particular chemical used as well as unexpected setbacks that can occur with weather. If the site is fairly free of noxious diseases and weeds, such as nutsedge, it may be better to plant on time and not fumigate than to fumigate and plant extremely late.

Currently, the preplanting fumigant with the shortest plant-back interval of 14 days is methyl bromide:chloropicrin (67:33), but this fumigant may not be available for use in your area unless your state received a Critical Use Exemption (CUE) granted by the EPA to the Eastern Strawberry Consortium (2006, 2007). Other registered fumigants for strawberries have plant-back intervals of 21 days or more.

As a general rule, you should begin land preparation for bedding and fumigation at least six weeks ahead of planting with the use of methyl bromide:chloropicrin (67:33) and seven weeks ahead of planting for Telone C-35.

It Is Important to Stay on Schedule

Here is a sample schedule for a grower in Zone 6 who wants to set out Chandler plugs in the second week of September and wants to use methyl bromide. For fumigants requiring a 21-day plant-back, plan on starting at least one week earlier (also refer to Table 10-1).

- **July — Week 4.**

  Whenever there is adequate soil moisture, begin preparing the soil so you can shape the beds and fumigate in early August. In an unusually dry July, you may be forced to overhead irrigate to get the land ready for chisel plowing and sub-soiling, if needed.

  Sub-soiling is needed every few years on heavy soils. This needs to be done in two directions, north-south and east-west, and it needs to be done deeply to loosen the soil and break up the plow layer (at 10 to 12 inches deep). Breaking up this layer will require setting the draft control so the V-ripper doesn't come up easily when it hits the hard spots. This operation requires extra horsepower!

  Be sure to incorporate your lime at this stage if you haven't done so already. Ideally the lime should be spread in June, just after the plastic is pulled and the beds are knocked down.

- **August — Week 1.**

  Have fumigant cylinders delivered to the farm and complete fumigation rig safety checks. Check with your fumigant supplier to be sure the cylinders are delivered on time and to ensure that the proper safety checks are used.

- **August — Week 2.**

  Broadcast N-P-K fertilizers and disk them into the soil to prevent nitrogen loss. Disk to a depth of 6 inches, breaking up clods until the soil has a "fluffy" texture.Don't use equipment that will compact the soil (a rotary hoe or rototiller may cause compaction).

- **August — Week 3.**

  Shape the beds and fumigate with methyl bromide + chloropicrin. Lay plastic mulch and drip tape.

  As the fumigant is injected, the beds should be immediately tarped with an embossed 1-mil black plastic mulch film that can be stretched by the mulch-laying and fumigation unit to give an extra tight fit over the bed. Also, stick tips (if you are rooting your own plugs). This is also the time to seed annual ryegrass.

- **September — Week 2.**

  Transplant plugs. Always try to allow three weeks between fumigation and planting, even though methyl bromide:chloropicrin (67:33) is a two-week plant-back material. This extra week will provide a cushion for possible weather delays that may occur.

  Likewise, for a 21-day plant-back fumigant, you really need to allow a four-week waiting period between fumigation and planting. Thus, fumigation with Telone C-35 should be done in the third week of August for an area that will be planted in the third week of September.

Order Planting Material and Handle Tips and Plugs Properly

Order runner tips or plugs on time. You must order your tips or plugs well before planting season (early to mid-September in Zone 6 for Chandler). Usually, the cutoff for placing these orders is in May. Tips should be shipped to your farm for plug rooting one month ahead of transplanting. For example, tips will need to be cut in the first week of August for transplanting plugs in the first week of September.

Store and handle runner tips carefully. Extended storage of the runner tips is generally not needed. Commercial tip nurseries can harvest fresh tips weekly starting in late July and continuing through mid-October. The tips are shipped by refrigerated truck to the grower's farm for delivery approximately 35 days prior to field transplanting. Tips may be stored up to two weeks at 34°F without deterioration in quality, but you should try to stick them as soon as possible after arrival.

The boxes containing approximately 1,000 plantlets must be stacked loose so that the cool air can circulate freely around the boxes. The strawberry tips are living, respiring plants and must be kept cool until the grower is ready to

root them under mist. The humidity in the cooler should be kept at around 75 to 80 percent relative humidity.

Root Tips With Moisture

Prior to rooting tips, additional plantlet preparation is needed to trim away excess runner-cords. An approximate 3/8- to 1/2-inch runner stub serves to anchor the plantlet until new roots develop. Fresh strawberry tips are best rooted under a fine mist that will wet the foliage yet put very little excess water on the soil. Keep moisture on the leaves until the plant is well rooted, about seven to 10 days.

As the roots form, the plants can be weaned from the mist and allowed to draw their moisture from the soil. Gradually reduce the mist over two to five days. Two weeks after sticking, you should be able to pull most plants from the cell with the root ball remaining intact. When that occurs, misting can be terminated.

This is a suggested misting schedule for greenhouse rooting:

- **Days 1 – 3:** Mist from 8:30 a.m. to 6:30 p.m. for 7 to 10 seconds of mist every 5 minutes.
- **Day 4 – 5:** Mist from 9:30 a.m. to 5:30 p.m. for 10 seconds every 7 minutes.
- **Day 6:** Mist from 10 a.m. to 5 p.m. for 10 seconds every 15 minutes.
- **Day 7:** Mist from 10 a.m. to 5 p.m. for 10 seconds every 15 minutes.
- **Days 8 –10:** Mist from 10 a.m. to noon and from 2 p.m. to 5 p.m. for 10 seconds every 15 minutes.
- **Days 11 – 13:** Mist from 10 a.m. to 3 p.m. for 10 seconds every hour. Move the plugs outdoors at the end of day 13.
- **Days 14 – 28:** Sprinkle for 5 minutes at 1 p.m. and possibly again in the late afternoon if temperatures are high.

Use the right rooting medium. Strawberry plugs should be grown in a specially prepared medium. Many different media are available, but a soil-less media composed of peat, sand, grit, vermiculite, perlite, polystyrene, or other materials is recommended. You will need about 4 cubic feet of media for approximately 1,000 tips, in 50-cell rigid plastic trays measuring 2 and 3/8 by 12 by 20 inches.

If the tips you receive from your supplier are quite variable in plantlet length, it is well worth the extra step to grade the tips by size into large, medium, and small lots. The large tips should be rooted in 38-cell trays, the medium tips rooted in 50-cell trays, and the smaller tips rooted in 60-cell trays. Sticking large tips (longer than 5 inches) in the same tray with small tips (2 to 3 inches long) will result in light competition and irregular root growth of the smaller, shaded tip plants. During misting, shaded tips are susceptible to botrytis infection.

Acclimate the plants. After the misting cycle is complete, move the trays to a fully exposed gravel pad for another two to three weeks of growth and acclimation before field transplanting. During this final field-conditioning phase, a single daily watering is suggested along with a weekly supplemental drench of a complete fertilizer material. A root-bound plug is desirable for mechanical transplanting; plugs for hand transplanting can be set before this stage is reached.

Planting

The ideal age of the plug for field transplanting is four weeks. Plugs held for six weeks in the trays are not as desirable and may have a slower initial growth rate in the field following transplanting.

Transplant Plugs to the Field

Plug plants pose less serious problems than freshly dugs for field transplanting. Pot-mulch planters or vegetable water-wheels can be used to mechanically transplant and water strawberry plugs. Careful size-grading of tip plants will produce more uniform plugs for efficient machine transplanting.

Depth

Do not bury the growing point of the plug plant by setting too deeply. Plug plants are not very deep; the rootballs are only 2 and 3/8 inches in depth for 50-cell trays. Your planting hole should not be quite as deep as the plug rootball: A 2-inch hole

is recommended for a plug from a 50-cell tray. Press the plug into the hole so that the top of the rootball is about even with the soil surface.

Even if you are mechanically setting plugs with a water wheel, it is a good idea to have one or two workers following the transplanter to brush a light layer of soil around the top of the plug's rootball without covering the growing point. This soil layer is helpful in keeping the plugs from wicking out. Without this slight soil layer, the exposed artificial soil media will wick moisture out of the plug very rapidly on sunny, windy days.

Starter Solution

Tray-grown transplants that have been under a plug propagation nutritional program do not require a starter solution at transplanting. A typical feeding program for plug transplants while they are still in the trays is to apply 1 pound of 20-20-20 per 100 gallons of water (in weeks three and four) before transplanting. This supplies roughly the equivalent of 240 parts per million (ppm) N.

Irrigation

A few hours of overhead sprinkler irrigation immediately following transplanting of plugs is recommended. A number of commercial growers in North Carolina use light overhead sprinkling (1/10 inch per hour) for the first, second, and possibly third day following transplanting for approximately 5 hours, 3 hours, and 2 hours per day, respectively.

Postplanting

Monitor the Plants

Plants should have three or more fully green leaves remaining at the end of the initial three- to four-week establishment period, regardless of whether they are fresh-dug plants or plugs. If the original leaves on a bare-root, fresh-dug plant or plug are lost to drought stress, plant establishment will be significantly delayed or set back, and spring yields will be significantly reduced. The number of leaves and total plant leaf area in the late fall/early winter can be correlated with fruit production the following spring.

Runners that develop in the fall can be removed to prevent competition with crown formation and floral bud development:

- Avoid removing runners until about three to four weeks following transplanting.
- Complete a follow-up runner removal operation at six weeks following transplanting if necessary.

It is also very important to achieve an adequate plant canopy by early winter as a good leaf canopy acts as an important crown insulator in winter. A 7-inch plant diameter is about ideal in mid-December. For good berry production, each plant should form one or two side stems (the branch crowns) and about eight leaves by mid-December (Figure 10-4).

Rooting is active throughout the fall and early winter as long as soil temperature is above 45°F and roots remain healthy. The roots also serve as storage sites for starch reserves during winter. Growers who push fall top-growth with extra nitrogen feeding may be doing so at the expense of starch accumulation in the roots. The stored starch is needed for vigorous growth and flowering the following spring, which will enhance berry size.

Figure 10-4. Plants should have about eight leaves by mid-December.

Ensure Fall and Early Winter Fertility

If beds were prepared as described under *Preplanting*, no fertilizer should be needed after transplanting. It takes strawberry plants (especially freshly dugs) two to three weeks to establish a new root system, and you should not

expect the plant's top-growth to look that healthy and vigorous during this initial period.

Once a new root system is established, the plants will be able to take advantage of the nitrogen, phosphate, and potash fertilizers that were applied prior to bedding. After three weeks, you should see the plants color up and begin to produce healthy new leaves. If preplant fertilizers were not applied, then it will be necessary to begin a fertigation program starting in the third week following transplanting.

Monitor for Diseases and Insects and Treat When Needed

A miticide application may be needed in the early fall to prevent two-spotted spider mites from reaching damaging levels in the late winter.

- Check plugs carefully for mites three to four weeks after transplanting.
- Make the miticide application before the late fall or early winter application of row covers if row covers are being used for winter protection.

Dormancy

Strawberry plants are dormant from late fall to early winter. The challenge during this stage of production is to protect plants from cold without creating conditions that encourage them to break dormancy too soon. To overwinter plants successfully, use row covers and windbreaks as needed. Monitor your plants for signs of early bloom and prevent diseases by removing dead leaves.

Use Row Covers

A fully dormant Chandler plant is quite cold hardy in midwinter, and it is usually grown without row covers in areas with average annual minimum temperatures of 5°F or higher. In zones colder than USDA Plant Hardiness Zone 7a, where average annual minimum temperatures can drop to less than 5°F, row covers must be used to overwinter plants successfully. Determining when to apply and remove them for your particular situation can be tricky, and it is important to consider both temperature and plant size (Figure 10-5).

Figure 10-5. Spunbonded row covers that weigh 1.5 ounce per square yard are ideal for the Midwest and are necessary for overwinter protection (applied in late fall); the covers are left in place until new leaves begin to develop in late winter. After they are removed, they can be re-applied for cold protection. The 1.5-ounce material can confer about 6 to 8 degrees of cold protection. Under severe wind-borne freeze conditions, the covers can be used in conjunction with overhead irrigation for maximum cold protection.

Delay covering for maximum plant hardiness. Delay the application of row covers until late November or early to mid-December. If you wait until late fall, plants should accumulate greater winter hardiness from exposure to lower temperatures than plants that are covered earlier in the fall for growth enhancement.

Apply covers early for growth enhancement. If the planting stage was delayed by one or two weeks, row covers can be applied as early as five to six weeks after transplanting to enhance fall growth and development. If row covers are not applied at this juncture, late plants will not have enough time to develop an adequate number of branch crowns for a full crop in the spring. In some cases, it also may be beneficial to apply covers in the early fall if temperatures have been unseasonably cool, and plant size is relatively small.

If covers are applied in early fall, the following steps are critical:

- Stunt the growth of the annual ryegrass in the aisles with a post-emergent herbicide — this must be done before the covers are applied.

- Inspect the undersides of leaves carefully for spider mites and aphids and take control steps if needed.

Remove covers early to slow crop development. Once covers are applied in the fall, they should remain in place until the end of dormancy when new leaf growth emerges from the crowns. New leaves begin to push out of the crowns by the middle of February in Zones 6 and 7. In the mountains and foothills of North Carolina, this is typically when the overwinter row covers are pulled off. Leave the covers rolled up in the field in case they are needed for a windborne freeze from late February through early March.

By removing the covers when the new leaf growth begins, you can slow down the crop in terms of how quickly it progresses from a tight-flower-bud stage to an open-blossom stage. If row covers stay on the crop for an additional two to three weeks, the crop comes out of dormancy and advances to the open-blossom stage while the weather is still very prone to Arctic clippers, wind currents that often lower temperatures to the midteens and gust to 20 miles per hour (mph) or greater.

Of course, row covers can be re-applied for windborne freeze protection. But there is little likelihood of saving open blossoms if more than 8 degrees of protection is required (spunbonded row covers that weigh 1.5 ounce per square yard [oz/sq yd] can confer about 6 to 8 degrees of protection, while 1.0 oz/sq yd covers can provide 4 to 6 degrees of protection).

Consider delayed removal for increased yields. Researchers in the North Carolina mountains are currently investigating the effect of leaving row covers in place for two to three weeks past the start of new leaf growth. A significant increase in Chandler yields was achieved in one season by leaving covers in place for two or three weeks after the start of new leaf growth.

The covers were then removed just before the open-blossom stage when buds have formed and appear white but have not opened — the popcorn stage. Although this ongoing research may prove to be quite valuable, it is based on just one season. Growers who wish to experiment with this strategy should do so only on a portion of their crop.

Use the most effective material. Research in North Carolina's mountains indicates that a 1.5 oz/sq yd spunbonded row cover material is the best all-round choice for colder plasticulture regions (USDA Zone 7a and colder). The covers come in various lengths and widths, and growers typically order covers in widths that can cover five or six rows.

Anchor the covers in place. Use gravel hold-downs to keep the row covers from blowing away and to preserve the cover. Shoveling soil on the edges of the row cover or using wire hooks will cause more rapid deterioration of the cover than using gravel hold-down bags placed every 5 to 6 feet along the cover edges (sometimes as close as 4 feet on high wind sites). Hold-downs can be placed even closer together on very windy fields.

The hold-downs are nylon mesh bags filled with enough gravel to weigh about 15 to 17 pounds each. The nylon mesh is available in 3,000-foot rolls. To make a hold down, pull off about 36 inches of the nylon to make one bag. Tie a knot at one end of the bag, fill the bag with the gravel (about two round-point shovels full), and tie off the other end. The stones at the bottom of the bag will flatten out nicely when dropped on the edge of the row cover. At the end of the season, collect the hold-down bags from the field and store until next year.

Remove Dead Leaves

In milder winters, strawberry leaves remain green. Where winters are more severe, the desiccating effects of cold winds will cause many dead leaves that need to be removed at the end of the dormant period. Many growers refer to this as leaf sanitation. Dead-leaf removal reduces botrytis pressure in March and during the early bloom stage. Leaf sanitation should not be done too early in the winter because a full plant canopy may be needed to protect plant crowns under severe freeze conditions.

Mid-February is usually the best time to schedule leaf sanitation following row cover removal. But when winters are warm, you may have to start this practice in January. Cold injury to leaves can be quite serious after a series of freezes. Plants that are covered during these freeze periods in winter will often not sustain any leaf injury and may remain green throughout most of the winter.

Preharvest

In the preharvest stage, strawberry plants break dormancy, make new growth, and begin to bloom. The prebloom phase begins as dormancy ends and new leaves emerge. New leaves begin to push out of the crowns by mid-February in Zone 6. This is typically when the overwinter row covers are removed — at the start of new leaf growth.

It is usually too late for leaf sanitation operations with tractor-drawn mechanical brushing equipment once new strawberry leaf growth has started because new leaf growth is very succulent and easily injured by rotary brushes. This is the time to pull up side-crowns that are caught beneath the plastic mulch and to remove weeds in the planting holes that were missed in earlier passes through the field. It is also time to hook up the drip irrigation system.

The main blossoming phase starts approximately four to five weeks after the beginning of new leaf growth in late winter, and continues for about one month. This is generally the most complex period in the crop cycle for the protection of blossoms from various pathogens and cold injury.

It Is Important to Maintain Proper Fertility

Make the first N fertilizer injection within a week after new growth has started. Research indicates that approximately 120 pounds per acre is an optimal N rate for Chandler strawberry production under plasticulture in sandy soils over the complete production season. Apply approximately one-half the N during the preplanting stage, and the remainder through drip irrigation starting in late winter soon after new growth begins.

Recommended N rates vary depending on the soil type. Deep sandy soils require the highest rates, followed by medium-textured soils; heavy-textured soils require the lowest rates. Do not wait too long after plants commence new leaf growth before initiating the prebloom N application. The general N recommendation to begin the season is 0.50 pounds per acre per day, which represents 3.50 pounds per acre on a weekly injection basis. The best way to determine the appropriate N rate for your plants, however, is to use a tissue analysis (Figure 10-6). Consult your local Extension service for information on where to get tissue analysis in your area or region.

Figure 10-6. Collecting leaves for tissue analysis. Randomly collect 20 to 25 trifoliates with petioles (leaf stalks) attached. (The leaf blades of strawberries are divided into smaller units called leaflets. The strawberry blade has three leaflets, thus the term trifoliate.) Next, snap off the petiole (right) from the leaf blade (left). At this time of year (late February), the petioles are about 2 inches long (earlier in the winter they are simply too short for sampling). Use a rubber band or bread ties to hold the 20 to 25 petioles together. Place both the 20 to 25 leaf blades along with the petioles in the pouch provided by the test lab.

Apply boron if needed on deep sandy soils. Wait until late winter or early spring to inject boron (B) through the drip system. Typically about 10 ounces per acre of solubor (20 percent B) is used if a tissue analysis shows deficient or near-deficient boron levels in the leaves. Apply solubor well before any blooms appear. Take care to apply boron accurately because it is extremely toxic if applied in excess. The difference between enough B and too much is small.

Continue to apply nutrients when plants begin to blossom. During the early bloom and main blossom phases, a weekly or bi-weekly schedule of N fertigation is recommended based on the results of a leaf tissue analysis. If leaf tissue analysis is not available, inject 0.75 pounds N per acre per day, the equivalent of 5.25 pounds N per acre per week.

With a weekly or bi-weekly feeding schedule, you can take corrective actions based on tissue sampling and petiole nitrate analysis during the prebloom period. Injecting N fertilizer every three or four weeks is not recommended.

Table 10-2. Petiole Nitrate N for New Growth, Prebloom, Bloom, and Harvest (ppm).

Stage of Development (weeks after dormancy breaks)		Low (ppm)	High (ppm)
New growth	Week 1	1,500	1,600
Prebloom	Weeks 2 to 3	4,000	6,000
Early bloom	Week 4	3,500	6,000
Mid-to-late bloom	Weeks 5 to 8	3,000	5,000
Harvest	Week 9	2,000	4,500
Harvest	Week 10	2,000	4,000
Harvest	Week 11	1,500	3,000

The petioles (leaf stalks) from trifoliate leaves are the best indicator of N status (nitrate N). The initial petiole nitrate levels before any drip fertilization is usually 600 to 1,500 parts per million (ppm). After the initial N feeding, these levels go up quite significantly (Table 10-2).

Tissue analysis can indicate whether any supplemental potash (K_20) or sulfur (S) is required at this stage. Tissue analyses and soil tests indicate that low sulfur is a real concern in numerous crops, including strawberries. Nitrogen levels are often elevated in the leaf tissue during the blooming and fruiting periods. This high concentration causes an imbalance between nitrogen and sulfur (the N:S ratio).

In turn, additional sulfur may be needed to offset the high level of N. Supply only as much N as required. If sulfur is needed during the spring, magnesium sulfate (Epsom salts) or potassium sulfate are good sources for drip injection. Sufficiency ranges for nutrients in the most recent mature trifoliate are given in Table 10-3.

Table 10-3. Sufficient Nutrient Ranges for Healthy Strawberry Plant Tissue.

Nutrient	Sufficiency Range
	%
N	3 – 4
P	0.2 – 0.4
K	1.1 – 2.5
Ca	0.5 – 1.5
Mg	0.25 – 0.45
S	0.15 – 0.40
	ppm
Fe	50 – 300
Mn	30 – 300
Zn	15 – 60
Cu	3 – 15
B	25 – 50

Provide Cold Protection

Strawberry flower buds begin to emerge from the end of February through early March in Zone 6. Unfortunately, in late winter, the entire zone is subject to advective or windborne freezes of various types (see Table 10-4). Throughout the blooming cycle, growers need to stay alert to conditions that favor frost formation at the ground level. Even when forecasts indicate that dew point temperatures and air temperatures will be in the upper 30s at the weather shelter

Table 10-4. Types of cold events.

Type of Event	National Weather Service Definition
Freeze	Wind speeds of more than 10 mph and air temperature below 32˚F.
Frost/freeze	Wind speeds are less than 10 mph and air temperature is below 32˚F.
Frost	Wind speeds are less than 10 mph and air temperature is above 32 F.
Hoar frost or white frost	Atmospheric moisture freezes in small crystals on solid surfaces.
Black frost	Few or no ice crystals form on the plant because the air in the lower atmosphere is too dry.

height (5 feet), a killing frost is still possible at the strawberry canopy level. Windborne freezes can cause devastating crop losses and delay the harvest by one or two weeks.

Row covers are usually the safest method of cold protection during the early bloom period. Under freeze conditions, overhead sprinkler irrigation is very risky due to a phenomenon known as evaporative cooling. Strawberry plants are most effectively protected during the early-bloom period when flower buds emerge with floating row covers of medium to heavy weight (0.9 or 1.0 to 1.5 oz/sq yd). Row covers of medium weight (1 oz/sq yd) can provide several degrees of cold protection, and this is usually adequate to keep emerged flower buds above their critical temperature of 22˚F when air temperatures are in the upper teens (Tables 10-5 and 10-6).

Losses of the earliest open blossoms (which have a critical temperature of 30˚F) will not be prevented with row covers when temperatures are in the low 20s and upper teens. However, the loss of the first three to four blossoms per plant with Chandler and Camarosa has little economic consequence because the earliest flowers typically develop into berries that are poorly shaped and hard to sell.

Use overhead irrigation during the main blossom period. A variety of cold events still can occur at the main blossom stage, including windborne freezes. But the majority of cold events during the main blossom period are frost/freezes (see Table 10-4). Overhead sprinkler irrigation is the most effective method for frost/freeze and frost protection of popcorn-size and fully open-blossoms.

Row covers are inconvenient during the main blooming period because they must be pulled back each morning following a night of cold protection (for bee and insect pollination), and a medium weight row cover (1 oz/sq yd) is not reliable for more than 3 to 4 degrees of cold protection.

These guidelines provide a basic overview of cold protection strategies for the preharvest stage. You will need special resources, however, to use these strategies effectively.

For detailed information on effective frost control using overhead irrigation, see: *Strawberry Plasticulture Advisory on Cold Protection,* Barclay Poling, April 2005, **http://www.smallfruits.org/SRSFC_News/StrawberryPlasticultureAdvisoryApril1505.pdf**

Harvest

After the blooms begin to bear fruit, the plasticulture strawberry harvest normally lasts around six weeks. But in cooler-than-average spring temperatures, the harvest can last up to two months. Because of high input costs for strawberry plasticulture production (about $10,000 per acre),

Table 10-5. Protection Effectiveness by Cold Event, Flower Stage, and Control Method.

Weather Event	Flower Stage	Row Cover Alone	Sprinkling Alone
Windborne freeze	Emerged flower bud	Good to Excellent[1]	Not recommended
	Open blossom	Fair	Not recommended
Frost/freeze	Emerged flower bud	Excellent	Excellent
	Open blossom	Fair	Excellent
Frost	Open blossom	Good	Excellent
	Popcorn	Good	Excellent

[1] The protection effectiveness of row covers alone will depend on cover weight, minimum temperature, and humidity.

Table 10-6. Critical Temperatures for Strawberries by Stage of Development.

Stage of Development	Approximate Critical Temperature (˚F)
Tight bud	22.0
Popcorn	26.5
Open blossom	30.0
Fruit	28.0

it is difficult to realize a profit unless you achieve a yield of 1 pound of marketable fruit per plant (15,000 pounds per acre) (Safley *et al.*, 2004). In favorable seasons, yields of 1.2 to 1.5 pounds per plant (18,000 to 22,500 pounds per acre) are possible with good management practices.

Postharvest

When the harvest is over, it is time to begin thinking about the next growing season. Destroy plants as soon as the harvest ends and incorporate lime when the beds are broken down. Although some growers reuse the plastic-covered beds for growing summer vegetable crops, July is the ideal time to begin preparing beds for the next plasticulture strawberry season.

Recommended Reading

Safley, C. D., E. B. Poling, M. K. Wohlgenant, O. Sydorovych, and R. F. Williams. 2004. *Producing and Marketing Strawberries for Direct Markets.* Publication No. AG-645. Raleigh: North Carolina Cooperative Extension, North Carolina State University.

The following web sites also contain a great deal of information related to the plasticulture of strawberry:

http://www.smallfruits.org/SmallFruitsRegGuide/Guides/2006/StrawberryIntegMgmtGuidefina12Jan06.pdf

2006 Southeast Regional Strawberry Integrated Management Guide

http://www.ca.uky.edu/agc/pubs/ho/ho16/ho16.htm