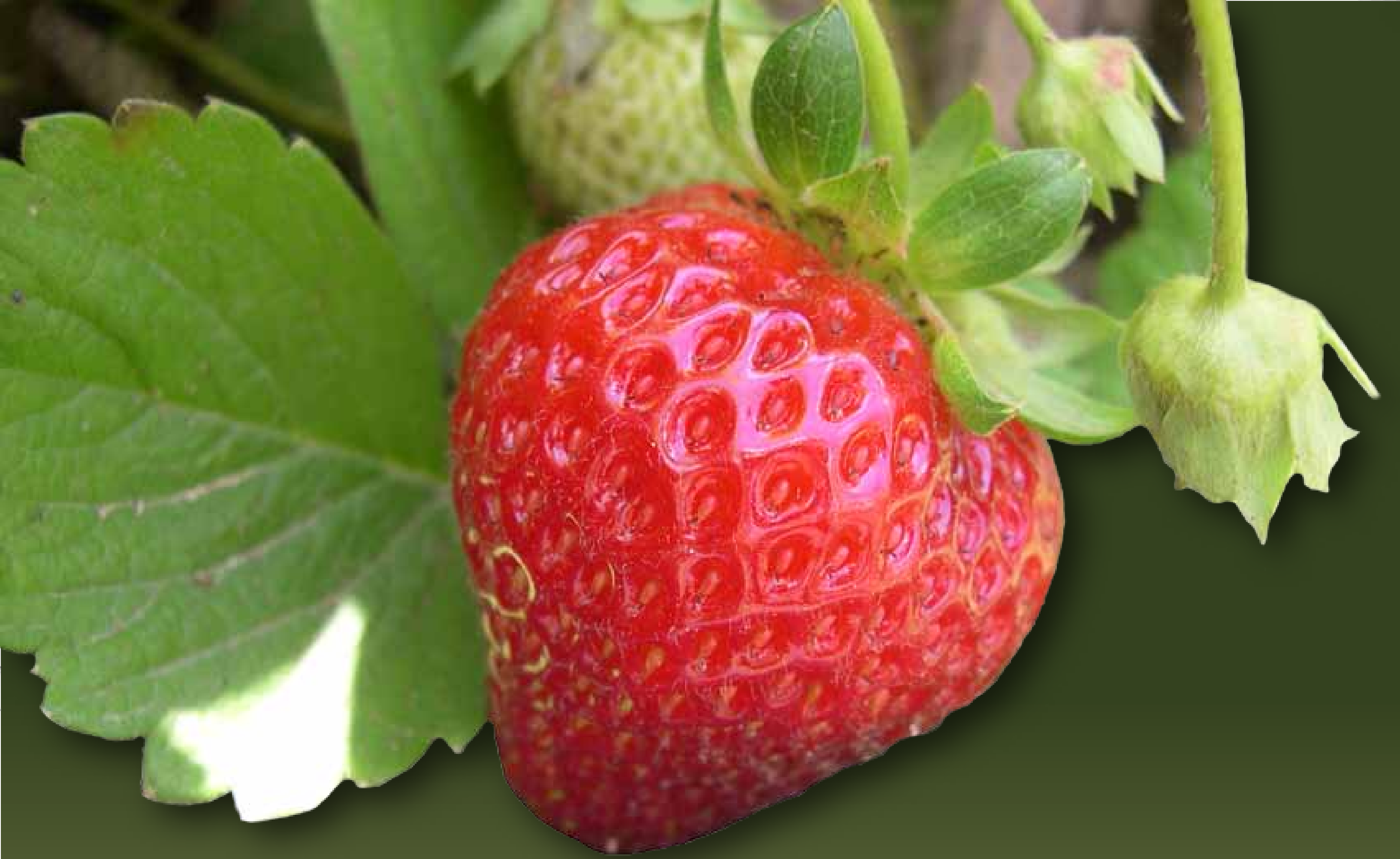

Season-Long Strawberry Production with Everbearers

for Northeastern Producers
EB 401

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Figs. 2.1–2.2; 3.2; 3.4–3.9; 3.11.1–3.13; 3.15–3.16; 4.9

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The Everbearing Strawberry Plant

The Promise of Everbearers

Strawberries are available in grocery stores 365 days a year. This is largely due to the fact that berries are shipped from different locations across the United States and around the world. However, in the eastern United States, fresh, locally-grown strawberries are only available at farmers markets, roadside stands, and grocery stores for several weeks during the late spring and early summer. This limited availability occurs mostly because the commercial strawberry production in the East is derived from June-bearing varieties, which have a brief production season.

Until recently, summer-long production of strawberries in the eastern United States was limited to backyard gardens, because the only obtainable varieties of everbearing strawberries had small fruit size and low yields. Now, the availability of new varieties and the adaptation of a plasticulture-based production system enable growers in the eastern states to produce and market fresh strawberries throughout the summer and into the fall. Trials in western Maryland and central Pennsylvania showed that everbearing varieties in a plasticulture system can produce as much as 1.8 pounds per plant, or 27,000 pounds per acre. Most producers easily achieved 1 pound of marketable fruit per plant from an annual planting. During the summer months of 2009, fresh local fruit sold for up to $4.00 per pound.

The primary purpose of this guide is to provide the opportunity for growers in the eastern United States to grow everbearing strawberries profitably. Information gained from research trials will be shared with growers in addition to the observations and experiences of the guide's authors and other significant contributors. Although the information presented in this manual reflects the University of Maryland Extension's current knowledge base; it should be noted that advances in plant breeding, culture, and understanding of the strawberry plant will continue to progress. As new information becomes available, growers will have the ability to make adjustments to meet the rapidly changing agricultural landscape.

Some History

Species of strawberry *(Fragaria)* that grow in temperate zones and fruit during the early summer have adapted to the climate by reserving the middle and end of the growing seasons for vegetative growth. The plants build on this vegetative framework, preparing to produce the next generation as seeds on the fruit for the following spring when growing conditions are usually lush. In this process, strawberries have evolved to initiate flowers when vegetative growth has ceased in the fall; short days and cool temperatures signal flower initiation. The flowers initiated during the fall will bloom in the spring and produce fruit within 30 days. Therefore, all of the June-bearing cultivars are *short-day plants*, according to the length of day under which they initiate flowering.

How did strawberries adapt to areas in the northern latitudes and at high elevations which experience frozen conditions during short days? The answer is that the strawberries jettisoned the "short day" mechanisms, and instead initiated flowers in August when days are still long. These very cold locations have short growing seasons, therefore causing plants to behave like short-day plants, with a crop being produced in the spring, and plants remaining vegetative for the remainder of their brief growing season. Royce Bringhurst, a well-known University of California plant breeder, transported plants growing at high elevations in Utah to California—a state that has lower elevations and longer growing seasons. As a result, it was proven that such plants are *day-neutral*—they lack the short day response of June-bearing types. (See "Additional Reading" for more information on this subject).

Although modern everbearers are classified as day-neutral, they, in fact are not. They do not really respond to day length. When light intensity and temperature are equivalent, everbearing strawberries produce more flowers, fruit, and runners during long days compared with shorter days. Everbearers in the northeastern United States can have a significant "June" or fall-initiated crop, similar to that of a June-bearing variety. But, everbearers do not become dormant as noticeably as June-bearers, which typically go through a strong leaf color change in the fall (not all varieties). Instead, everbearers continue to flower.

Most strawberry varieties, whether June-bearers or everbearers, have a chilling requirement that must be met before the plants can resume vigorous growth in the spring. Specific chilling requirements of different varieties of June-bearing and everbearing strawberries vary, and there is some overlap between the two types. The lesser winter dormancy of certain cultivars is due to the efforts of plant breeders, especially those who breed for lower latitudes where winter temperatures are warm. However, strawberries characteristically benefit from cold conditions at 28-45˚F, and preferably between 30-38˚F, and in excess of 400 hours.

Typically, the vegetative growth of chilled plants is more vigorous than non-chilled plants. Non-chilled everbearers that have been planted in warm areas such as southern Florida may lack vegetative vigor which can be manifested by shortened petioles and fruit stalks (peduncles) and trusses, lack of runnering, and slower crown development. Planting during the fall, in regions with more than 3 weeks of daytime highs below 45˚F, fulfills the chilling requirement prior to spring flowering. Also, the growth of everbearers and June-bearers will become more vegetatively vigorous the following year. Thus, everbearers retain some ability to sense day-length while retaining their chill or winter response mechanisms.

Some conditions exist where everbearing strawberries will not flower despite being nominally day-neutral. For instance, short days that have poor light and cold or freezing temperatures inhibit flowering, while anther formation and pollen production can be severely reduced. Flower initiation and development also can be inhibited when temperatures are high (above 85˚F). Under these conditions, fruit size suffers as well as fruit firmness, fruit sugar levels, and aromatic content. Fruit production is often depressed during the summer months in areas with extended hot summers (including many eastern United States locations with elevations less than 2,500 feet); however, high yields can occur during the late summer and fall. In high elevation areas with cool summers (i.e. locations above 2,500 feet in the East, and even higher elevations in the western United States), fruit production remains consistent throughout the summer with peak production in mid-summer. In northern locations where temperatures are cooler, high elevation is not necessary for successful summer production. One of the most successful everbearing industries is in Quebec, Canada, at elevations less than 400 feet.

In light of these differences, growers must carefully select the plant type, planting date, mulch color, fertilization, variety, and plant density that will maximize the yield while maximizing plant health and fruit size. An understanding of the differences between everbearing and June-bearing strawberries will allow growers to make well-founded decisions when managing their plantings.

Crown Numbers: June-bearers vs. Everbearers

Where maximum yield is achieved in the temperate zone areas (from Georgia northward), June-bearing plants in plasticulture production typically have 3-4 crowns per plant by spring flowering. Also, due to the short harvest season, June-bearers do not become very dense during fruiting. In contrast, everbearing plants with 3-4 crowns by first flower could have as many as a dozen crowns by the end of the first growing season. The majority of the harvest season would produce plants that are too dense and disease prone, and the late-season fruit would be small. Although crowns are necessary for yield, an overly dense field, either matted row or plasticulture, requires crown thinning to reduce crown numbers. Thinning crowns is a labor intensive and expensive practice; therefore, it's advisable to initiate the season with a single crowned everbearing plant that has been newly set or planted during the previous fall. The majority of dormant plants obtained from a nursery are single-crowned. Everbearing plants should be planted relatively late to minimize the number of branch crowns formed; this is a sharp contrast to the strategy for June-bearers which thrive upon branch crown development. Differences in variety and climate also will affect plant performance. Generally, warmer climates produce more runners and fewer branch crowns.

Dormancy and Overwintering

As previously mentioned, the everbearing strawberry plant becomes dormant reluctantly, and is forced to stop growing once the plant simply runs out of growing conditions. This process occurs to a lesser degree than most June-bearers due to the fact dormancy is triggered by short days and low temperatures.

It should be noted that it is not unusual for everbearers to continue to flower through the first light frost. For instance, the variety Everest has been harvested along the protected shores of Lake Erie in mid-December. Everbearers develop winter or short-day anatomy (shortened petioles that are more prostrate) which show that they are responsive to winter conditions. Reduction in plant growth is caused by low sun angle and shorter day lengths, the loss of leaf function due to shading from floating row covers (usually occurs 4-6 weeks after applying the row cover), and the reduction in temperatures. Flowers can be initiated during the winter for the everbearer and the June-bearer because flower initiation does not require a significant amount of energy. However, while dormancy may prevent flowers from growing in the June-bearer, the everbearer does not express flowers because the trusses require sugar in order to elongate, and short days limit photosynthetic sugar production and elongation of trusses. On warm winter days or early in the spring, everbearers can produce short trusses that are sometimes hidden in the crown which are winter-tender. When flowers actually grow through the winter under conditions not favorable for photosynthesis, anther development is poor and the fruit may show symptoms of frost injury such as cat-facing and puckering.

Winter care of everbearers in areas colder than Zone 7 is less difficult because flower trusses that have been killed can be replaced by newly initiated trusses at any time. Overwintering of everbearers has been quite successful as far north as Quebec with varieties such as Seascape, Everest, and Evie 2.

As a precautionary note, there are indications that everbearer plants with less intense dormancy can lose vitality in long-term storage at 30-38˚F at a rate faster than dormant June-bearers. When planting dormant bare-root plants, growers must ensure that the plants have been continuously "frozen" at 30˚F, shipped cold, and planted quickly as possible.

Chapter 2
Economics

Budgets for everbearing strawberry production are similar to those for June-bearing plants production systems. The major difference in everbearer production is increased labor costs for harvesting due to the long harvest season and higher yields. Therefore, production during the off-season when prices are highest may result in a large portion of the profits. Some of the costs of everbearer production are higher than June-bearer production; however, the cost in other areas is lower due to the fact that the steps involved in renovation, overwinter protection, and frost protection during the spring are eliminated if the plants are grown only for one season. The labor savings created by eliminating these steps as well as the decreased need for frost protection infrastructure makes the everbearing system attractive for small-scale integrated production.

In order to maximize profitability, growers must maximize both yields and prices for their specific operations. Minimizing costs may or may not have a positive effect on profitability; however, cutting corners often negatively affects yields. Chapters 3 and 4 of this manual discuss maximizing yields, as the demand for the product in specific growers' markets determines the price that berries can be sold. Some growers report a strong market for strawberries at off-peak times of the year, while others do not. In some cases, consumers are skeptical that the strawberries in the marketplace in months other than May or June are truly local. Generally, the market for off-season berries is somewhat weak when buyers prefer to purchase an individual crop during its traditional season. However, the market is much stronger when the majority of buyers are willing to purchase berries all year round. The strength of sales through different marketing channels varies. For instance, some growers report weak sales for everbearing strawberries at their farm stands during the fall, but stronger sales at farmers' markets for the same berries.

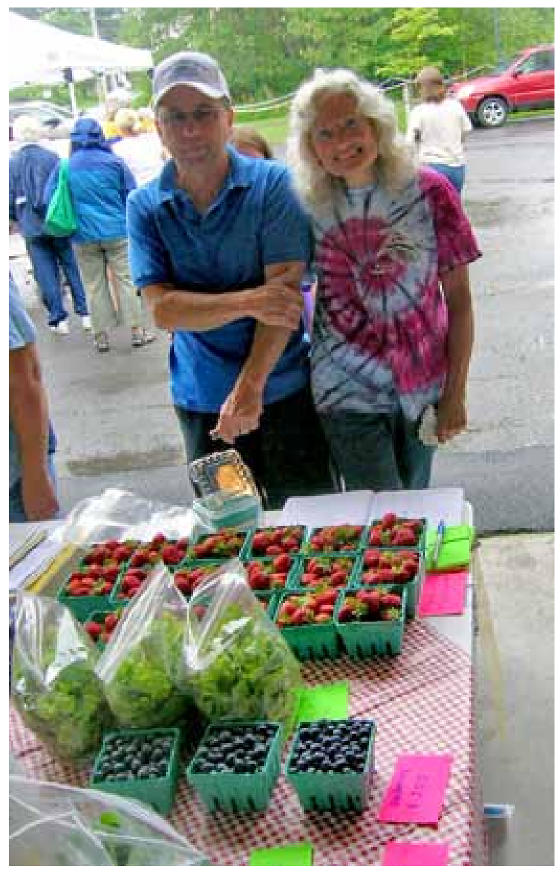


Fig. 2.1 Everbearing strawberry fruit can be very profitable at farmers markets during summer months, fetching as much as $3.00 per pint or about $4.00 per pound.

It is important to fully comprehend the production costs of everbearing strawberries. If growers cannot produce sufficient income from everbearing strawberries to cover both the costs of producing the berries and paying oneself a sufficient wage for effort, then it's probably not feasible for the grower to remain in business for the long-term. The following budgets are intended to help growers (1) plan for their enterprise, and (2) ensure that growers are aware of costs in order to make an accurate assessment of their profitability.

Fixed Costs

Fixed costs are those costs incurred as the owner of equipment or property; these costs do not vary with acres in production. For example, the cost for the land, buildings, equipment owned, and real estate taxes would remain the same whether the grower produces strawberries, another type of crop, or leaves the land fallow. Fixed costs are very challenging to estimate for a production budget—as these costs vary greatly from farm-to-farm, and thus are not included in Table 2.1. However, a land charge is included which may cover costs associated with owning the acres in production.

The budget presented in Table 2.1 was designed for an annual everbearing plasticulture planting—provided that plug plants are planted in the spring, the fruit harvested during the summer and fall, and the plants removed in the fall. If the planting is delayed throughout the winter for production a second year, additional costs will be incurred to account for winter protection, spring frost protection, and planting care and harvest until production has been discontinued. Many growers only produce fruit for the second year during the spring harvest season; this second spring crop can be quite substantial; however, berry size often decreases markedly.

Variable Costs

The cost of establishing everbearing strawberry plantings is higher than the cost of establishing June-bearing plants. Cost per plant of everbearing varieties may be 20-50 % higher than for June-bearing varieties (depending upon the variety purchased).

In areas with short growing seasons and late spring frosts, the only feasible planting method is to begin with plug plants that were produced from dormant bare-root plants. The cost of plug plants will range from $0.30-$0.40 per plant. Although the cost of plug plants are 2-3 times higher than bare-root plants, the additional cost can be negated by 0.1 pounds of increased fruit production, provided that the fruit is sold at $3.00-$4.00 per pound. For everbearing plants, higher costs are associated with insect and disease control. Because these plants produce fruit for 15-20 weeks, additional applications of insecticide and fungicides may be required.

Labor costs for planting, weeding, or depositing straw are estimated at $800 per acre per year. This estimate was obtained from June-bearing plasticulture, which includes (1) labor for row cover application and removal, and (2) frost protection. However, with more intensive management of everbearers throughout the summer, producers should expect to spend more time maintaining and operating certain tasks such as trickle irrigation. Thus, required labor was estimated to be similar. Fruit picking labor was estimated at $0.36 per pound, which was based on industry standards of $0.50 per quart. Since the everbearing strawberry season is extended throughout many weeks, the amount of fruit to pick at any one harvest is much lower than with June-bearing varieties, therefore increasing the harvest time per area. However, since everbearing varieties in annual systems usually produce smaller plants, less time is needed to locate the fruit, and results in roughly similar time requirements for harvest per pound of fruit.

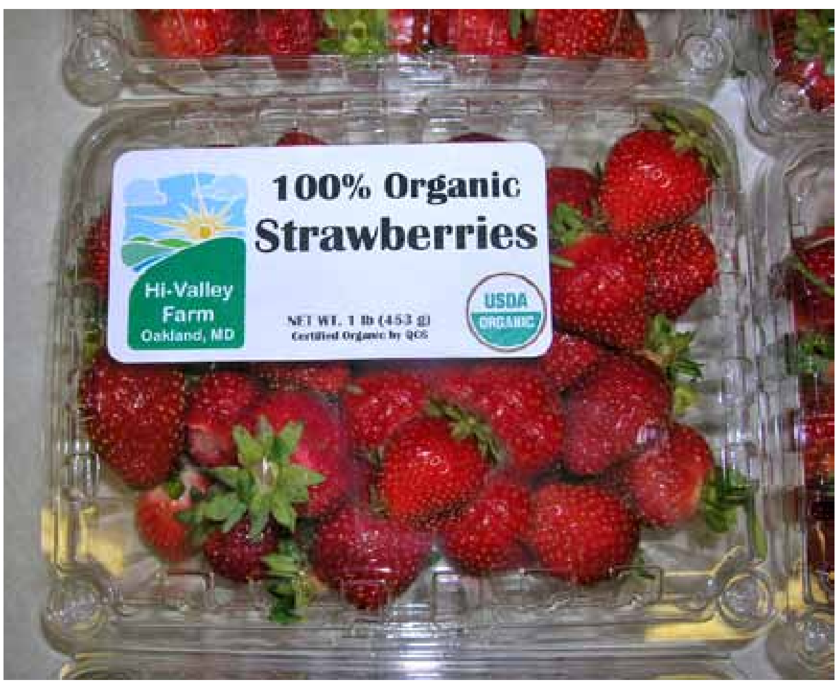


Fig. 2.2 Organic offerings of locally produced everbearing strawberries can be very attractive to wholesale purchasers for grocery stores.

Table 2.1.

			Number Plants	1000	1,000	15,000
			Acres		0.07	1.00
Income						
Item	**Unit**	**Price**	**Quanity**	**% Saleable**		
Strawberries	per lb	$3.00	1.00 lb	70%	$2,100.00	$31,500.00
Expenses						
Item	**Unit**	**Price**	**Quantity**			
Soil Prep - Machinery Costs						
Plowing	per acre	$19.80			$1.39	$19.80
Roto-tilling	per acre	$50.00			$3.50	$50.00
Fertilizer Application	per acre	$9.85			$0.69	$9.85
Plastic Laying	per acre	$50.00			$3.50	$50.00
Insecticide/Fungicide Application	per acre	$10.00	8 applications		$5.60	$80.00
Planting	per acre	$50.00			$3.50	$50.00
Fertilizer/Insecticide						
19-19-19 Dry Fertilizer	per lb	$0.45	200 lbs per acre		$6.30	$90.00
20-20-20 Soluble Fertilizer	per lb	$1.00	200 lbs per acre		$14.00	$200.00
Fungicide	per acre	$250.00			$17.50	$250.00
Insecticide	per acre	$200.00			$14.00	$200.00
Supplies and Materials						
Black Plastic	per roll	$95.00	2 rolls per acre		$13.30	$190.00
Drip Tape	per roll	$150.00	1 roll per acre		$10.50	$150.00
Strawberry Plug Plants	per plant	$0.35			$350.00	$5,250.00
Containers (pint pulps)	per container	$0.05	933 containers		$46.65	$700.00
Flats	per flat	$0.80	78 flats		$62.40	$936.00
Straw for between Rows	per ton	$150.00	2 ton		$21.00	$300.00
Labor						
Harvest	per lb	$0.36	700 pounds fruit/1000 plants		$252.00	$3,780.00
Other Labor (planting, etc)	per acre	$800.00			$56.00	$800.00
Fixed Costs						
Land Charge	per acre	$150.00			$10.50	$150.00
Total Costs					**$892.33**	**$13,255.65**
Return to Management and Investment					**$1,207.67**	**$18,244.35**
Return per Pound					**$1.73**	
Return per Plant					**$1.21**	

Return per Plant					
	yield/plant				
price/lb	**0.5**	**0.75**	**1**	**1.25**	**1.5**
$2.00	$(0.19)	$0.30	$0.73	$0.98	$1.15
$2.50	$(0.02)	$0.42	$0.86	$1.30	$1.73
$3.00	$0.16	$0.68	$1.21	$1.73	$2.26
$3.50	$0.33	$0.95	$1.56	$2.17	$2.78
$4.00	$0.51	$1.21	$1.91	$2.61	$3.31

Assumptions

Labor: 2 hours per picking X 3 pickings per week X 15 weeks = 90 hours per season for 1000 plants

Equipment is based on PA Custom Rates in 2009 which includes equipment, tractor, and fuel

Chapter 3
Annual Plasticulture Production of Everbearing Strawberries

In the eastern United States, spring planted, in-ground raised bed, plasticulture is the most reliable and economical method to produce an everbearer crop without taking extraordinary measures. At this time, plasticulture is the predominant system utilized for everbearer production in the eastern United States and around the world. When considering alternative production methods, growers should carefully review the other systems and options described in Chapter 4. Also, it is advisable to explore the pros, cons, and tips of the various systems; this information was based upon currently available data.

Plasticulture production requires certain equipment and infrastructure, specifically bed makers, plastic layers, water for trickle irrigation, and sufficient capital to afford the plants. Some of the advantages of the plasticulture system include:

- Warmer soil in spring for earlier planting and vigorous starts.
- Controlled soil moisture to avoid wet roots in extended periods of rain.
- Less soil water evaporation during summer months.
- Less need for chemical weed control.

The combination of a climate, the cultivar selection, and management is necessary to justify the cost of plasticulture. During various trials in Maryland and Pennsylvania, everbearer yields of 1.0-1.8 pounds per plant were obtained from spring-planted plug plants in this planting system. These trials produced returns that exceeded costs by a considerable margin. The goal of this chapter is to share information regarding the production methods used in this region where high yields were obtained.

Pre-Plant Considerations

When considering soils and site selection, many of the same criteria that apply to strawberry production in other systems also may apply to everbearer plasticulture production. For example, strawberries, other fruit, or solanaceous crops (e.g. tomatoes, peppers, potatoes, etc.) must not have been planted during the preceding 5 years due to the susceptibility of strawberries to soil diseases, specifically verticillium wilt. Soils must be well-drained, irrigation should be available, and crop rotations should be planned to minimize other potential issues. These topics and others are discussed in detail in the *Mid-Atlantic Berry Guide for Commercial Growers* (Demchak, K., et al., 2010) or other relevant University of Maryland Extension publications for specific regions. (See "Additional Reading").

Site Preparation

A soil test should be conducted 6 months prior to planting in order to determine fertility needs. Organic matter percentage must be requested, if not reported as part of the standard results by the lab the grower is using. If a site has a history of fruit production, it is advisable to conduct testing to determine the nematode population.

Pre-plant fumigation is no longer routinely used or recommended in the Mid-Atlantic if crop rotation recommendations are followed and there are no known problems which could be resolved by fumigation. Biofumigation may be an option for growers who must fumigate but would prefer to use an environmentally-friendly approach; however current technologies and specific recommendations are still in development. Current suggestions for utilizing biofumigation are discussed in Chapter 4 under "Matted Row Production," along with modifications to make biofumigation useable for a plasticulture system.

When rotating to soils that have not been tilled or that have had perennial grasses or weed problems, the soil should be tilled during the fall before planting. It will be unlikely that herbicides can be applied early enough in the spring to obtain proper weed or grass control and also allow time for tillage and early planting. Applying herbicides to grass sods during the fall will provide superior control of grasses and weeds, while simultaneously maintaining a residue cover that will help to avoid soil erosion during the winter. Cover crops can be established on the field provided that (1) the grass has been killed during the late summer and early fall and (2) the primary tillage has been completed. This formula will provide the most effective combination of soil protection and workable soil for an early spring planting. Systemic and burndown herbicides such as glyphosate (Roundup, Touchdown, etc.) or paraquat (Gramoxone) should be applied to the ground at least ten days before the soil will be plowed or tilled. These products require that the plants are actively growing and temperatures are above 50˚F for superior results.

Types of Plants and Plant Sources

In the East, dormant bare-root plants are usually the sole source of planting stock readily available for spring planting. Fortunately, dormant plants are the least expensive stock for annual plantings. Dormant plants either can be planted directly into the field during the spring, or they can first be grown in multi-cell trays for a short period of time in order to form plug plants. Plug plants grown from dormant plants have the advantage of being established in containers prior to field planting, which means that they can reliably begin to grow regardless of soil and weather conditions. Once planted in the field they establish quickly and produce fruit in 45-60 days.

To make plug plants, it is necessary to schedule the delivery of dormant stock from a nursery in mid-February or 60 days before planting in the field. Then, plants are planted into 32-cell trays, since a relatively large cell size is necessary to accommodate the large root systems of dormant plants. Growers should use a peat and perlite soilless mix that will provide sufficient drainage through the use of a relatively high proportion of perlite, and mix in the light rate of a 3-4 month 13-13-13 or similar slow release fertilizer as listed on the container. Dead leaves, petioles, and half of the roots should be trimmed off by hand prior to planting the plants in the cells. For optimal root growth, maintain cool temperatures (as close to 50°F as possible). Plants must not be allowed to freeze; however, when planting time arrives, it is important to expose the plants to the elements to help them harden off. When plug plants are grown at higher temperatures, they have the tendency to become leggier and more susceptible to wind damage and desiccation once they are planted. Flower blossoms should be removed from plants while they are being grown in the trays.

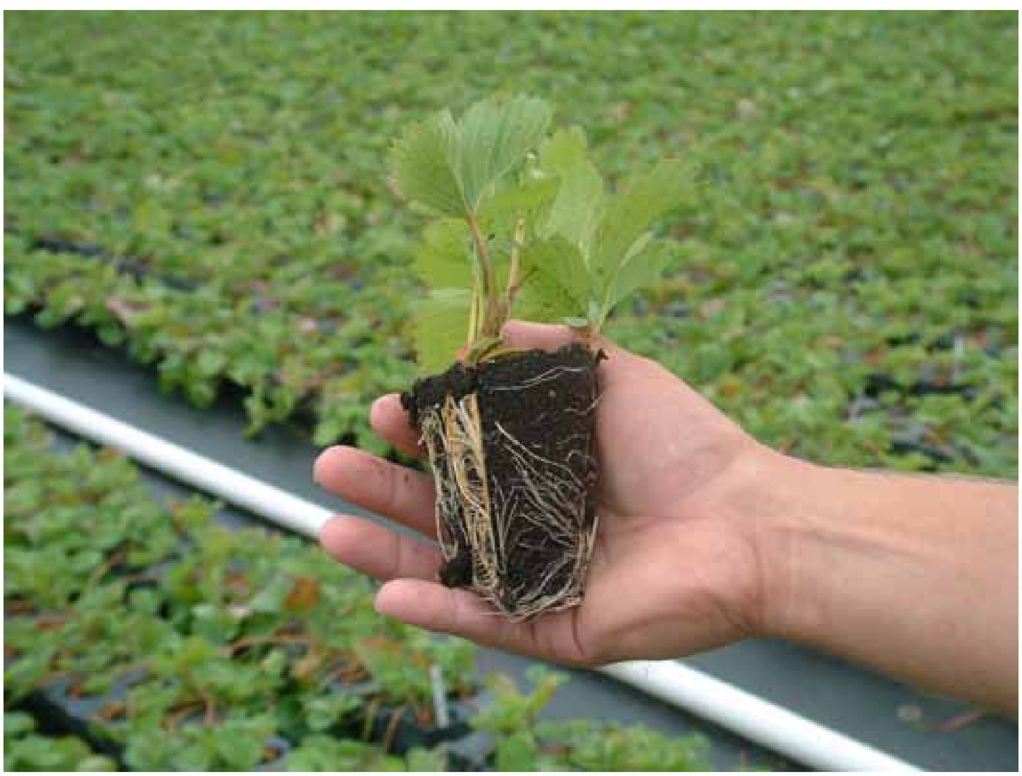


Fig. 3.1 Everbearing strawberry plug ready for planting.

When possible, growers can use greenhouse space as an alternative method for making plug plants for spring planting. First, the grower should obtain standard 40 or 50 cell plug plants during the early fall—as if conducting a fall planting in the field. The plug plants are then transferred to larger cells in October and allowed to overwinter in unheated greenhouses (heated only if the temperatures get below 22˚F). By spring, every effort should be made to keep the plants short to avoid legginess. Growers can accomplish this task by keeping plants in low temperatures and ensuring that they are not given supplemental light. Exposure to low or slightly sub-freezing temperatures for a week will harden plants somewhat; then plants can be planted during the spring.

When ordering plants, growers must be aware that plant densities are quite high in plasticulture systems. Depending on the spacing used, 11,000-15,000 plants per acre are required. More details on plant spacing options are provided below.

Varieties

Outside of California, few varieties of everbearing strawberries have been developed in the United States. Two exceptions include Tristar and Tribute—which were released in 1981 by the United States Department of Agriculture (USDA). These two varieties are disease resistant and have good flavor; however, the fruit size and firmness is not of commercial standards. Varieties currently used in the eastern United States are derived from breeding programs in California as well as the United Kingdom. Seascape was developed at the University of California at Davis, and is the most widely used everbearing variety in the East. Evie 2 was developed by the Edward Vinson breeding program in England. The Evie 2 variety is more vigorous, mildew resistant, and can be more productive, especially when planted in unfumigated soil. Seascape and Evie 2 have become the dominant varieties available for commercial production in the East. Available everbearing cultivars are listed below and further discussed.

Albion. Released in 2006 from the University of California. Albion is very widely grown in California. Grower reports from the Mid-Atlantic are positive regarding the quality, despite low yields. Albion produces a high percentage of marketable fruit that are quite firm and even endure prolonged wet spells. Due to its size and shape, Albion is reminiscent of Camarosa or Diamante (one of its parents). Also, the fruit

Fig. 3.2 Albion everbearing strawberry variety.

produced is elongated and can be somewhat uneven in appearance. Albion has a perfect red color and has acceptably good flavor when fully ripe. Albion plants are very vigorous, and produce a large number of runners in the North. Despite these plants producing much foliage, the fruit can be picked very fast due to extremely large fruit size. Albion is resistant to verticillium wilt, and is moderately susceptible to powdery mildew and fruit anthracnose. This variety is recommended on a trial basis for the Mid-Atlantic region.

Fig. 3.3 Albion fruit.

Aromas. A day-neutral from the University of California introduced in 1997. It is high yielding, and somewhat poorer quality than the more recent introductions. In a Pennsylvania trial, the fruit were relatively large for an everbearer and had a rich red color, but were a bit too firm. Aromas have fair to good flavor and are susceptible to verticillium wilt and common leaf spot. This variety is not recommended for the Mid-Atlantic.

Diamante. Introduced in 1997 by the University of California. Its fruit is large and firm, but low in sugars and aroma. This variety has good color and shape. Diamante yielded less than Seascape in Pennsylvania. It is not recommended for the Mid-Atlantic.

Everest. Introduced by Edward Vinson Plants, Ltd. (United Kingdom) in 1998. This cultivar's strong point is its high yields on suitable sites. The main problem with this berry is its smaller size, very soft fruit, and lack of flavor in warmer weather. Its flavor improves during cool fall conditions, and some growers find the quality to be acceptable. Everest produces few runners. This variety is very susceptible to anthracnose fruit rot and verticillium wilt, therefore growers must be careful with rotations if other verticillium wilt-susceptible crops were planted in the field. Everest is resistant to red stele and powdery mildew. This variety is recommended for trial.

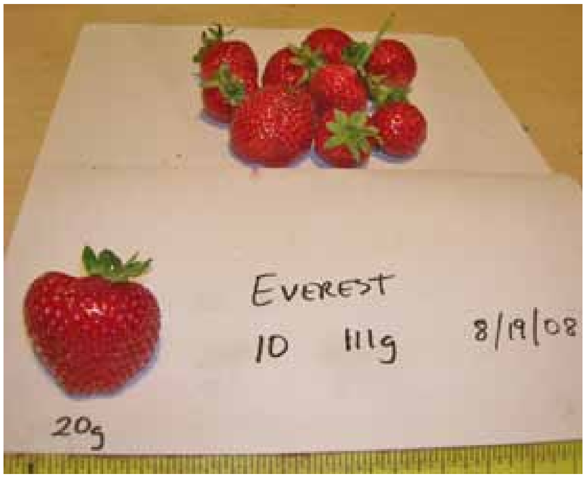


Fig. 3.4 Everest fruit.

Evie 2. Introduced by Edward Vinson Plants, Ltd. (United Kingdom) in 2001. Evie 2 fruit is large, attractive, and uniform, but its color is light and texture is soft. Its flavor is average to somewhat acidic. In a Pennsylvania trial, yields were considerably lower than those of Seascape or Everest. In Maryland grower trials, yields have been very good. Evie 2 plants are very vigorous and somewhat powdery mildew resistant. This cultivar tends to utilize the space that is available to it by growing larger, but yields do not necessarily increase in proportion to the larger plant size. This variety is recommended for trial.

Fig. 3.5 Evie 2 everbearing strawberry variety.

Fig. 3.6 Evie 2 fruit.

Evie 3. Introduced by Edward Vinson Plants, Ltd. (United Kingdom) in 2003. The Evie 3 is high yielding and similar to Everest in productivity, however its fruit is soft, light-colored and low on flavor. No source of plants for growers in the United States was located as of this writing.

Fern. Released in 1983 from the University of California. Fern berries are soft and light-colored and not very flavorful. This variety has average productivity. Fern is not recommended.

Fort Laramie. Released in1973 from the USDA in Cheyenne, Wyoming. This variety is winter hardy, but it is susceptible to a number of fruit-rotting diseases and powdery mildew. Its fruit is small and soft under warm conditions. This variety is not recommended for the Mid-Atlantic.

Hecker. Released from the University of California in 1979. Hecker is usually low-yielding compared to other everbearing cultivars. This variety is not recommended for the Mid-Atlantic.

Mara Des Bois. Released in 1991 by Marionnet SARL, a nursery and breeding company in France. This variety is considered a "gourmet" berry and is prized by some chefs. Its berries are small, but very flavorful and aromatic. Mara Des Bois is susceptible to fruit anthracnose. This variety is recommended for trial in protected culture, but not for field production.

Monterey. From the University of California. Only recently has Monterey been obtainable outside of California, where it produces large firm fruit on vigorous plants.

It is susceptible to powdery mildew. At this time, there are no recommendations available for the Mid-Atlantic states due to lack of testing.

Portola. From the University of California. Only recently has Portola been obtainable outside of California, where fruit is large, and somewhat light in color. At this time, there are no recommendations available for the Mid-Atlantic states due to lack of testing.

Quinault. Released in 1967 from Washington State University. This variety is commonly available in nursery catalogs, but of little utility in a commercial setting. It is not recommended for the Mid-Atlantic.

Tribute. Released in 1981 from the USDA in Beltsville, Maryland. Tribute's flavor is somewhat more mild than Tristar, but it is still tart. Its fruit size is relatively small and firm; the plants are fairly vigorous. This variety is only recommended for trial or backyard production.

Tristar. Released in 1981 from the USDA in Beltsville, Maryland. This variety has good flavor, but can be tart. Tristar's fruit is firm and its size is small in hot weather. It is resistant to red stele, verticillium wilt, and powdery mildew. Tristar is recommended only for trial or backyard production.

San Andreas. From the University for California. San Andreas has only recently become obtainable outside of California. Its fruit is large and somewhat light in color. This variety is reported to have more resistance to diseases than previous University of California varieties as well as a better flavor and fruit quality. There are no recommendations available for the Mid-Atlantic states due to lack of testing.

Seascape. Released in 1990 from the University of California. Seascape is the most widely grown cultivar for everbearing production in the eastern United States and Canada. It's typically quite productive, and produces medium-sized and medium-red fruit with notable sweetness and has a nice shape. However, powdery mildew has been a problem during some years. Seascape is susceptible to red stele, but is resistant to leaf scorch. This variety is recommended in the Mid-Atlantic region.

Fig. 3.7 Seascape everbearing variety.

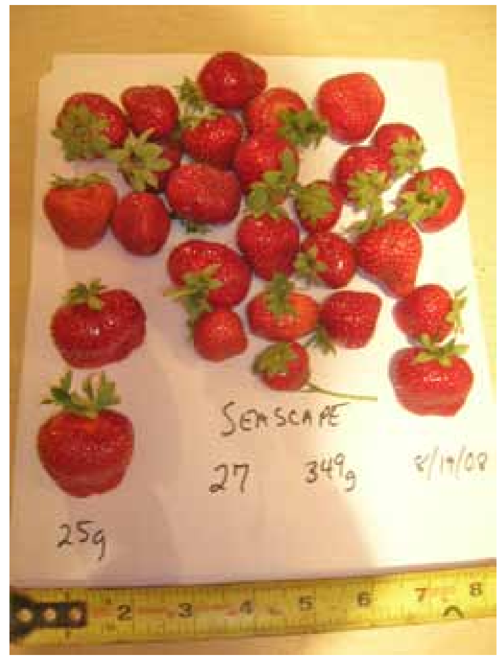


Fig. 3.8 Seascape fruit.

Selva. Released in 1983 from the University of California. In a Pennsylvania trial, Selva fruit was soft and light-colored but had little flavor. Its size was average. This variety is not recommended for the Mid-Atlantic.

Fertility

For everbearing strawberries, adequate nutrients must be available throughout the growing season to produce high yields. The soil pH should be 6.0-6.5 for maximum availability of plant nutrients. Some of the plant nutrients are integrated into the soil prior to making the bed and applying the plastic. At a later time, additional application of nutrients is made through the drip tape. Either organic or inorganic sources can be used to provide nutrients.

Organic inputs such as composts, manures, and green manure crops can provide adequate nutrition. Be aware that a couple of weeks may be required before sufficient nutrients from organic (i.e. carbon-based) sources are mineralized into plant useable forms. Incorporating manure, green manure crops, and compost into the soil 2-3 weeks prior to planting will help solve this problem. Also, due to low mineralization rates, only 10-30 % of the total nitrogen in the compost will be available during the first year. This means that as little as 2 pounds of obtainable nitrogen may be available per ton of compost in the year of application; therefore, large quantities of organic nutrient sources may be needed. Because the quantities of nutrients vary greatly with the source of organic matter, it is strongly recommended that an analysis of the material be conducted to avoid over- or under- application of nutrients. Some providers of organic composts may already have this information.

Nutrients from commercial inorganic granular fertilizers are more quickly available, and thus fertilizers should be incorporated into the soil just prior to forming beds and applying the plastic. When nutrients are applied through drip irrigation, the fertilizer solution should be applied 1-2 times per week during routine watering cycles.

Organic and inorganic fertilizers may be applied to provide the needed combination of nutrients.

The everbearing strawberry offers an opportunity for a new fruit industry in the eastern United States. However, because this is a new industry, the data that establishes a nutrient regime (especially for nitrogen fertilization in cool climates) is being compiled from information in various locations for both June-bearers and everbearers. Considerations regarding the application and specific nutrients requirements are described below.

Nitrogen (N). The current recommendation is to integrate 60 pounds of nitrogen per acre prior to planting. Many high analysis granular fertilizers that provide nitrogen such as 10-20-20 or 19-19-19 use ammonium phosphate as a source of readily available phosphorus. These types of fertilizers may be incorporated into the beds pre-plant to meet nitrogen requirements, but if the additional phosphorus or potassium is not needed, it may unnecessarily load the soil with phosphorus or potassium and potentially contaminate the groundwater.

Phosphorus (P). Compared with nitrogen and potassium, phosphorus requirements for strawberry plants are low. Thus growers should use low phosphorus analysis fertilizers to avoid exceeding recommended levels of phosphorus, especially in Maryland were nutrient management laws prohibit the use of nitrogen and phosphorus above levels recommended by nutrient management plans. Starter fertilizers may be of value, particularly when soil temperatures are cool at planting. In Europe, monoammonium phosphate is commonly used at a rate of approximately 10 pounds per acre of actual nitrogen.

Potassium (K). Potassium is an important nutrient for the development of the strawberry flavor. Large amounts of potassium are transported into the fruit during ripening. When fertilizer is applied through the drip irrigation system it may be advantageous for growers to switch to a soluble fertilizer with a higher level of potassium a week before strawberries are expected to ripen. Commercially available soluble fertilizers with analysis such as 9-15-30 or 4-10-40 are available (See Table 3.3 Fertilization).

Calcium (Ca). Calcium is adequate in most soils in the eastern United States and moves into the plant with the water flow. Thus, symptoms of calcium deficiency most commonly appear when plants are moisture-stressed, rather than truly calcium deficient. The constant cropping of everbearing plants, especially in cold or hot weather when root growth is severely reduced, also can result in poor uptake of calcium despite adequate or excess calcium in the soil. Reduced calcium can result in reduced firmness, especially if temperatures are hot. Applying calcium sprays may have little benefit; therefore, it may be more profitable to maintain healthy roots and sufficient moisture levels. If there are concerns that calcium may be deficient, a grower can lime before planting or use soluble calcium nitrate as the source of nitrogen, provided that levels of phosphorus and potassium are adequate.

Magnesium (Mg). Magnesium levels are generally sufficient in the soil for strawberry production within the Mid-Atlantic region. In situations where magnesium needs to be added and the soil pH is sufficient or shouldn't be raised, Epsom salts (magnesium sulfate) or Mag-Ox can be used. If the pH also needs to be raised, dolomitic lime can be used.

Boron (B). Boron deficiencies occur most often in deep sandy soils and sporadically in other soil types. Boron is needed for cell division and pollination; therefore, the symptoms of boron deficiencies are poor fruit "seed" set and poorly formed spindly leaf development. Boron is important at the time of flower development and during runner production. Once signs of boron deficiency are detected, it will be too late for currently developing fruit, but the addition of boron to plants that show deficiency symptoms early in the season may correct the problem for fruit developing later in the season. Tissue samples should be monitored for boron levels in suspected boron deficient areas. If tissue sample levels fall below 25 parts per million, an application of Ð pound of boron per acre (10 ounces of Solubor, which is 20 % boron) should be applied through the drip irrigation. Since boron can be toxic to plants at high levels, accurate and even applications of boron are important. Further, annual or preventative applications of boron should not be applied except on sandy soils where low boron has been a documented problem.

Organic Nutrients

There has been increasing interest particularly from organic growers regarding the use of organic-based nutrients from manure and compost. Manure and compost have the advantage of providing micronutrients and increasing organic matter. The difficulty of using manure and compost is accurately calculating the nutrient content and availability and ensuring that nutrients will be available throughout the growing and harvesting seasons. It is unlikely that a producer can meet the nutrient needs of the plants without applying too much of some nutrients, especially phosphorus. A reasonable balance is to use organic nutrients for some portion of the required nutrients and to compensate deficiencies utilizing commercial fertilizers.

For certified organic growers, alternative sources of nutrients that have been approved for organic production must be utilized. One of the most challenging aspects of growing everbearing strawberries organically is how to effectively add more nutrients throughout the season and in second year plantings—this is particularly true for plasticulture systems. Only a limited number of products that have been approved for organic production can be applied through drip irrigation.

Raw animal manure may be readily available on farms that have animal operations in addition to fruit and vegetable production. Although, nutrients from animal manures in these situations are very economical because they are a by-product and do not require shipping from distant manufacturing or mining facilities, many factors may limit the application of manure to the ground for strawberry production. The first consideration is that manure should be applied at least 6 months prior to the first fruit harvest. Manure should not be spread on frozen ground, thus for spring plantings, manure must be applied the fall prior to planting the crop. For late summer and early fall planting, manure needs to be applied early in the spring after snow has disappeared and the ground is not frozen. Raw manure should be incorporated using primary tillage within 1 hour after manure application if most of the ammonia in the manure is to be conserved. Since the crop cannot be planted for 4 months (calculating fruit production will start 2 months after planting) after the manure application, a cover crop should be planted to control soil erosion and prevent leaching of nutrients, especially nitrogen.

Although compost can be applied to crops while they are being harvested, realistically, producers should incorporate the compost into the soil just ahead of bed forming and planting. Care should be taken to apply the compost with a uniform method. Because compost is an organic nutrient, it will take a couple of weeks for microorganisms to mineralize the nitrogen. The microorganisms require soil temperatures above 50°F in order to convert large amounts of nitrogen to plant available forms. This information should prompt producers to apply and incorporate compost into the soil 2-3 weeks before planting strawberry plants.

Calculating the nutrients available from compost and manure must begin with a lab analysis. It is recommended that growers collect a representative sample at least 1 month before the manure or compost will be used. When using commercially produced compost, a nutrient analysis may be available; however, manufacturers are not required to provide this data. Once the analysis has returned from the lab, the mineralization rate for the manure or compost must be calculated. The mineralization rate is used only to determine the amount of nitrogen that will be available, and will largely depend on the components that make up the manure or compost. Manure from beef cattle that have been fed mostly hay and are on bedding that contains a large amount of sawdust or straw will mineralize slower that manure from poultry or hog operations where the animals are fed mostly grains and little or no highly fibrous bedding is used. Mineralization rates areavailable in other publications for some common manure and composts. (See "Additional Reading). If the manure or compost is being applied to soil for the first time the mineralization rate, the amount of material applied, and the percentage of nitrogen in the material can be multiplied to roughly calculate the amount of nitrogen available.

If multiple years of manure or compost have been applied to the field, the amount of nitrogen that would have become available during previous years must be subtracted before calculating the amount of remaining nitrogen that will become available in the current year. Then, the amount of nitrogen that will become available from new applications in the current year can be added. All of the phosphorus and potassium in manure and compost will be available during the first growing season.

Irrigation

When growing plants in a plasticulture system, irrigation is a necessity. Everbearing plants are expected to produce high yields in the warmest part of the year and thus can require large amounts of water. Soil type determines the amount of water that the soil can hold. Clay loam soils can hold between 1.75-2.5 inches of water per foot of soil depth, compared with sandy loam soils which can hold 1.25-1.75 inches of water per foot. Soils with higher amounts of clay can hold more water, but they also hold water more tightly. In general, heavier soils require irrigation less frequently than sands, but the additional amount of water that is available from a clay soil is less than one might expect. Also, plants placed in clay soils may be stressed before the soil appears to be dry. Soils high in organic matter generally will require less frequent irrigation. Irrigation systems in the eastern United States fall into two main types: overhead and subsurface drip systems.

Overhead Irrigation

Because the plastic serves as a barrier to water infiltration, overhead irrigation in a plasticulture system is used for purposes other than that of watering the plants. Water applied through overhead systems in hot summer weather may be used to decrease the plant temperature through evaporative cooling, thus decreasing plant stress. This may be of particular value if an unusually warm spell occurs during plant establishment. However, since using overhead irrigation wets both foliage and fruit when used during the production season, the potential for problems with plant diseases is increased. If plantings are kept for a second year, overhead irrigation may be used for spring frost protection.

Drip Irrigation

Drip irrigation is a surface or subsurface system that delivers water to or below the soil surface, thus eliminating most of the evaporation that makes overhead systems inefficient. Since considerably less evaporation occurs than with sprinkler irrigation, much less water is required—saving as much as 80 % of the water compared with other systems. Other advantages of drip irrigation include compatibility with plasticulture, reduction of disease due to wetting of the foliage, and the ability to easily apply soluble fertilizers throughout the growing season through the drip irrigation system.

The soil type affects the distribution of water within the soil as it is delivered from drip irrigation. Coarser soils with larger amounts of sand have limited lateral movement of water from the emitters. Water movement in soils with larger amounts of clay will move well laterally. To compensate for the various ways water moves in the soil, growers with sandy soils should consider selecting drip tape with emitters that are closer together (4-6 inches) and placing two drip tapes per raised bed, thus providing for greater wetting of the entire bed. Care must be taken to ensure that the tape is not directly in line with the planting row to avoid punctures. For growers that have soils with higher levels of clay and/or organic matter, it is sufficient to use one drip tape down the middle of the bed and emitters that are 12 inches apart. Drip irrigation tape should be installed 3-4 inches below the soil surface at the time of making beds and laying plastic.

Choices in drip irrigation tubing are centered around the thickness of the drip tape and the water flow rate. Drip tape that is 6-8 mil in thickness is adequate for plantings that are expected to be used for only one growing season. Plants that are expected to be fruited for two seasons should have 8-10 mil drip tape. The flow rate of the drip tape will affect the amount of water that is applied in a given amount of time; however, a range of flow rates can be used to apply a given amount of water. A typical flow rate for drip tape is 0.45 gallons per 100 feet per minute. Another factor to consider when selecting the drip tape is the flow rate of the water source. To provide adequate water to the entire area that will be irrigated, the amount of water outputted from the emitters in any area that is being watered cannot exceed the source flow rate.

Bed Formation

When considering the distance between beds, spacing is essentially determined by equipment. Typically, beds are on 6-8 foot centers (i.e. the distance from the center of one bed to the center of the next is 6-8 feet). This results in 7,240 feet of plasticulture row per acre if beds on 6-foot centers, and 5,445 feet if beds are on 8-foot centers.

The formation of raised beds creates many advantages for the strawberry plant including:

- Increased topsoil depth to overcome problematic areas such as plow pans and poorly drained subsoils.
- The soil volume available to hold water and nutrients is increased.
- Excessive water from rainfall can easily move away from the root systems.
- Better air circulation around the plants.

The soil needs to be well-worked prior to formation of raised beds. Sod and surface residue can make forming beds and planting difficult as well as become problematic for later weed control.

Raised beds are formed with a variety of machines either before the plastic is applied, or more commonly as the plastic is being laid. Usually beds are approximately 30 inches wide. The soil which will be formed into the raised bed must be friable and free from large clods and organic residue. The soil also should be dry enough not to pack excessively; however, it should not be so dry that it loses the ability to form. Obviously, in heavier soils, constructing larger beds would require multiple passes with a bed shaper before the plastic and trickle tube is laid.

Most beds are formed by collecting soil from a 5-6 foot wide area and forming it through a pan type bed press. It is important that the soil is uniformly pressed in the bed, the bed must be full, and the center should be somewhat crowned (i.e., higher in the middle, to run excess water off the plastic). Otherwise, pockets will form under the plastic, and water will collect in puddles on the plastic rather than draining to the sides, resulting in fruit "rainspotting" and fungal infection of the fruit.

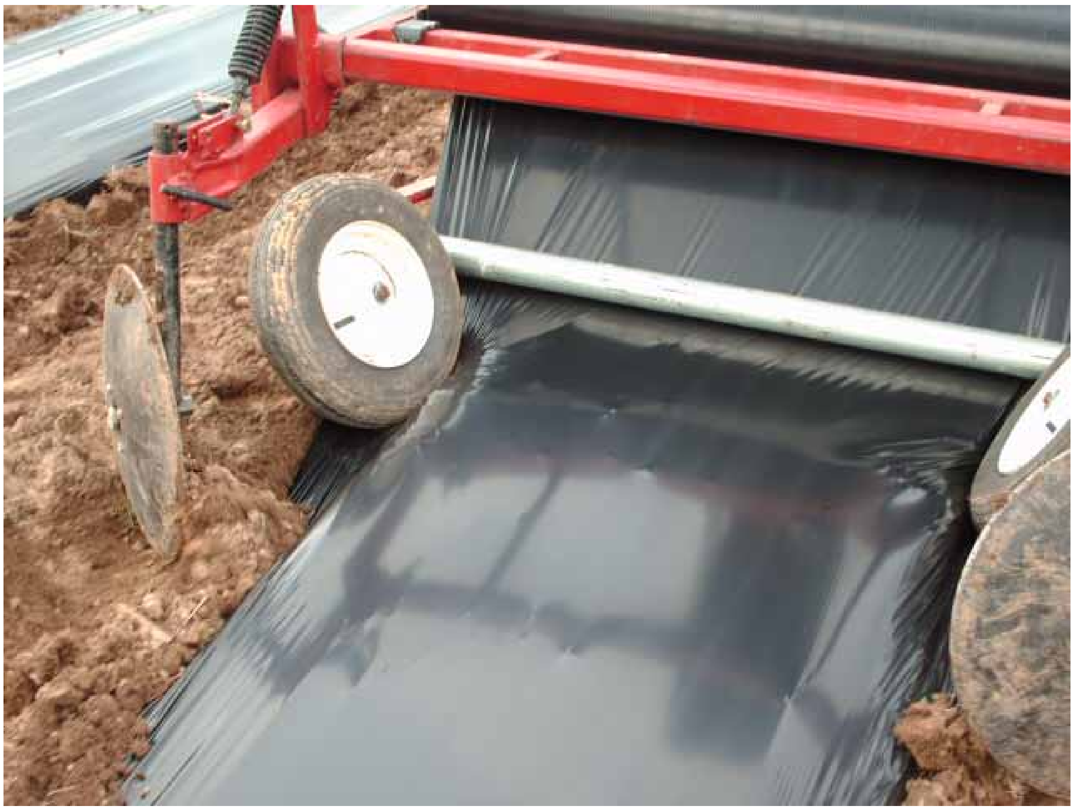


Fig. 3.9 Forming the bed and laying plastic and drip tape.

The raised bed configuration is generally determined by the size of the bed maker. Cooler sites, particularly those with very low winter temperature, typically have lower beds—this may keep the plants from being exposed as much during the winter. However, it should be noted that the height of beds is not always correlated with latitude. Beds in Quebec are usually higher than beds in Appalachia (400 miles south). Perhaps bed height is more correlated with ease of soil "bedding," particularly with the amount of larger rocks present in the Appalachian Highlands or the depth of the topsoil.

Plastic mulch is applied to the bed at the time the bed is formed or immediately afterwards. Plastic mulch can be a very effective for controlling weeds provided that (1) care is taken when applying the mulch, and (2) holes have not been created in the mulch by pickers and critters such as deer and dogs.

Commercial plastic mulch is available in a variety of colors and thicknesses ranging from 0.5-1.5 mil. Since everbearing strawberries remain in the field for at least 6 months, a minimum of 1 mil plastic should be used. If there are expectations that the planting may be extending throughout winter for a second season, 1.5 mil plastic should be considered. Plastic is available as smooth or embossed. Embossed plastics usually stretch more effectively over beds and do not expand and contract as much as smooth ones. Expansion and contraction of plastic contributes to loosening of mulch from raised beds.

Plastic mulch is available in a variety of colors. Standard black plastic is used for the majority of vegetable production; therefore, it is readily available and less expensive than other colors. Black plastic has the advantage of collecting much of the solar radiation which substantially warms the soil and results in earlier production. Heat is moved into the soil through conduction; consequently, it is important that the plastic is tight against the bed. Black plastic with planting holes has been shown to raise the temperature of the soil 3-5°F over bare soils.

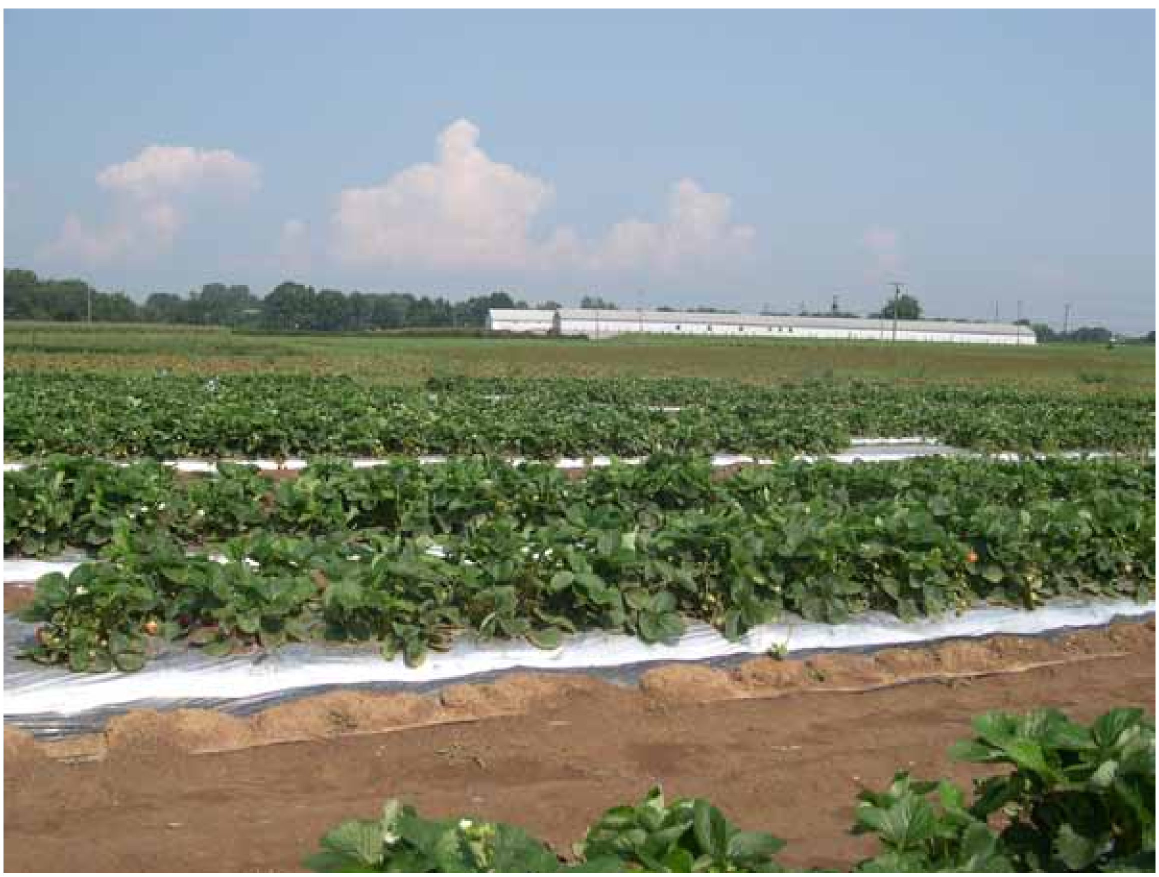


Fig. 3.10 Reflective aluminum plastic mulch.

Despite the advantage of warming the soil early in the season to maintain everbearing strawberry fruit production during the summer months, the plants—including the root systems must be kept as cool as possible. White on black and aluminized reflective mulches have been shown to reduce soil temperatures by 3-4˚F more than black plastic, which results in soil temperatures similar to that of bare ground. In an evaluation of black, white, and aluminized plastic in Garrett County, Maryland, black plastic warmed the soil in the early spring which resulted in a slight increase in early fruit production. However, it was determined that the heat of summer significantly increased fruit production on aluminized plastic. Although differences in overall annual production were insignificant between the colors of plastic, the increased production during hot summer months, when local production of strawberries is limited, can result in higher income, therefore justifying the extra cost of more expensive aluminized plastic. In hotter climates, the advantages of using aluminized plastic to reduce summer soil temperatures and increase plant performance are expected to be greater.

Plant Establishment

Two to three days prior to planting, growers must ensure that the irrigation system is working and that the bed is thoroughly wetted. Typically this is accomplished by turning on the trickle irrigation system, and allowing it to run until the soil has been visibly wetted just to the outside of the bed. Since the drip tape may be installed in the middle of the bed it may take many hours—typically at least 3-4 hours in order to wet the soil laterally until the plants can be planted. Wetting the beds 2-3 days before planting allows the soil to drain prior to planting, so that the soil is moist but not muddy.

Planting Dormant Bare Root Plant Material

Dormant bare-root plants can be easily planted by placing the roots on the plastic and pushing the plant through a pre-punched hole in the plastic into the soil with a flat stick, such as a thick wooden paint stirring stick, a dandelion digger, or an asparagus knife. After the roots have been inserted, growers must ensure that the bottom of the crown of the plant is just under the soil level. If the growing point in the center of the crown is covered, the plants will likely rot. The plants should have overhead water applied shortly after planting if the weather is hot. Once plants begin vegetative growth, plants must be protected from temperatures below 25ºF. The best method for protecting the plants is to cover them with floating row covers.

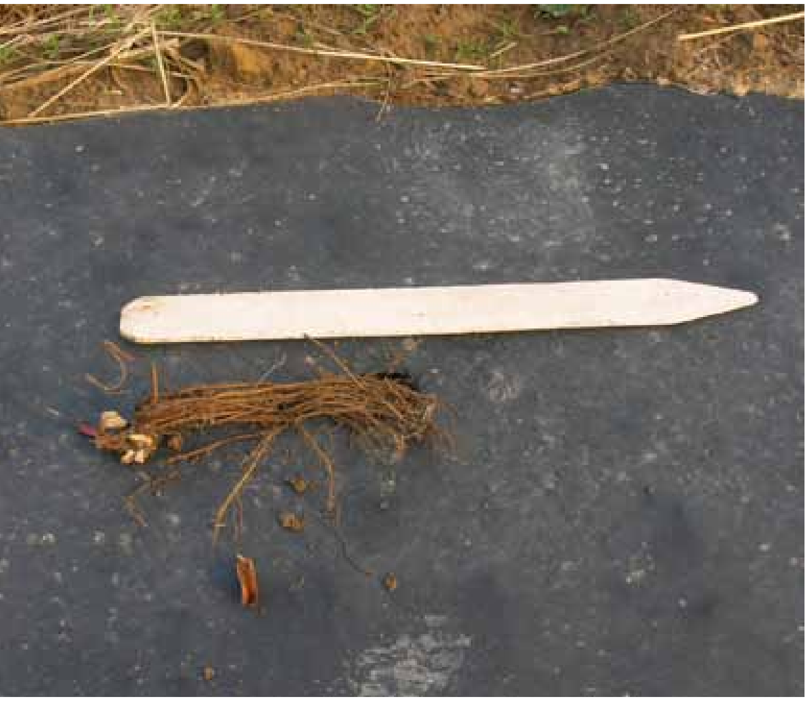


Fig. 3.11.1 Bare root plant with planting stick.

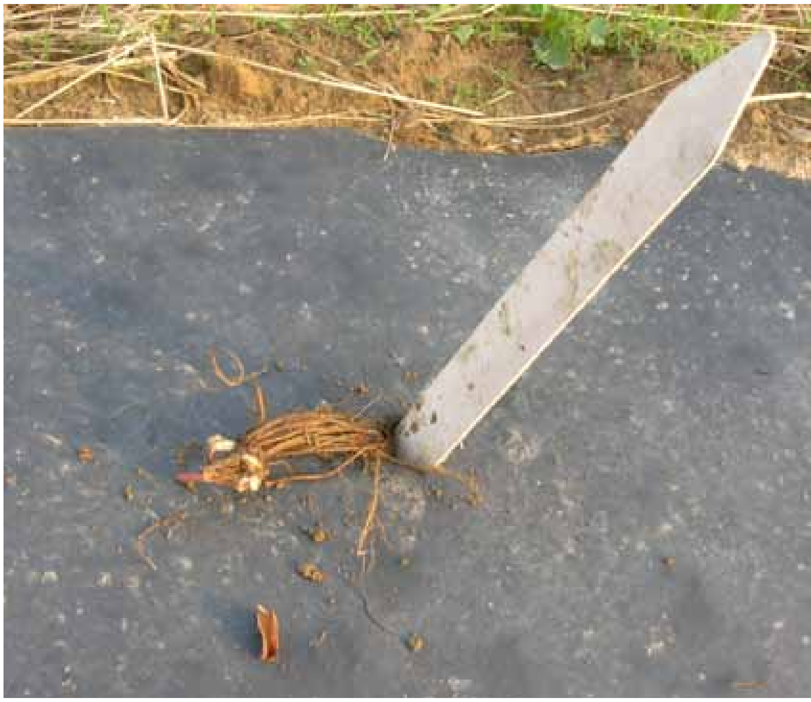


Fig. 3.11.2 Push the plant through the plastic by placing the stick about 1/3 way up the plants root system.

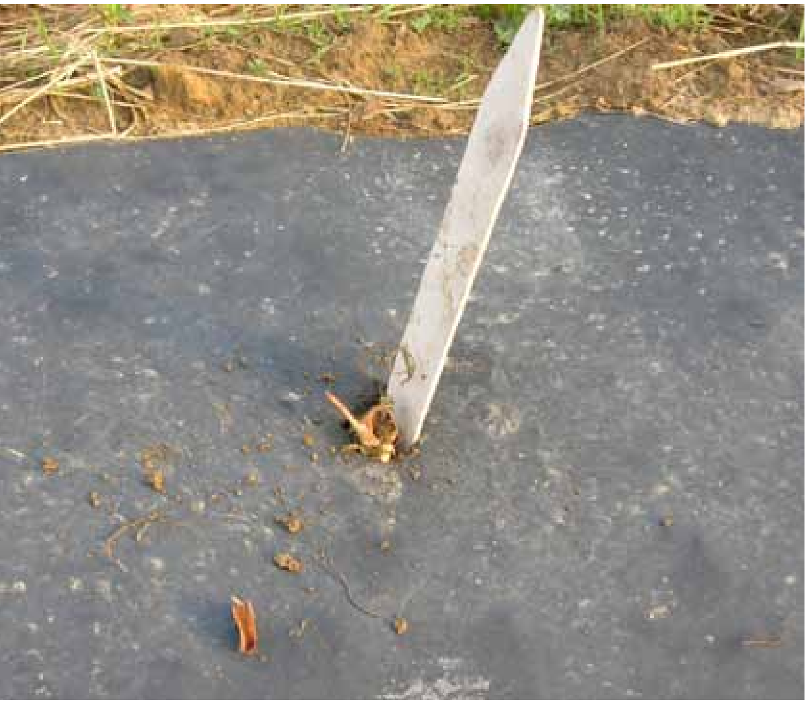


Fig. 3.11.3 Push the plant in until the crown is just below the plastic.

Fig. 3.11.4 Properly planted bare root plant.

Above: Fig. 3.11.5 Bare root planting 1 week after planting.

Left: Fig. 3.11.6 Bare root planting 2 weeks after planting.

Flower trusses should be removed for 2-3 weeks after dormant field-planted plants begin to flower in order to allow the plant to establish and have leaf surface to support later fruit production. Otherwise the plant's vigor will suffer, total fruit production will be reduced, and the plant will be less able to withstand attack by diseases or insects. To compensate for the loss of fruit by flower removal, it is recommended to plant dormant plants 6-8 weeks before the last frost date.

Planting Plug Plants

Small numbers of plug plants can be planted by hand using a trowel or dibble to create a hole in the plastic to set the plug. Larger plantings can be planted with a water wheel planter that punctures the plastic, and creates a hole which fills with water. The grower riding the planter should push the plug into the hole. Usual planting dates for setting plug plants in the field are 3-4 weeks before the last expected frost date. Before planting, growers must ensure that there is a period of at least 3 days when frost is not expected and preferably, the ground temperature is >50˚F at a 3-inch depth. Flowers should be removed from plants while they are in trays (see "Types of Plants and Plant Sources" for directions on producing plug plants), flower removal from plug plants once planted in the field is not necessary. In a study in Garrett County, Maryland, fruit size and yield per plant were compared between plants that had blossoms removed for 0, 2, and 4 weeks after planting. Plants that had their blossoms removed after field planting did not have significantly larger fruit size or higher total yield. In fact, the removal of blossoms delayed the harvest of the first fruit. The only reason producers may wish to remove blossoms from plug plants is if they want to delay fruiting; however, this would generally defeat the initial purpose of producing plug plants.

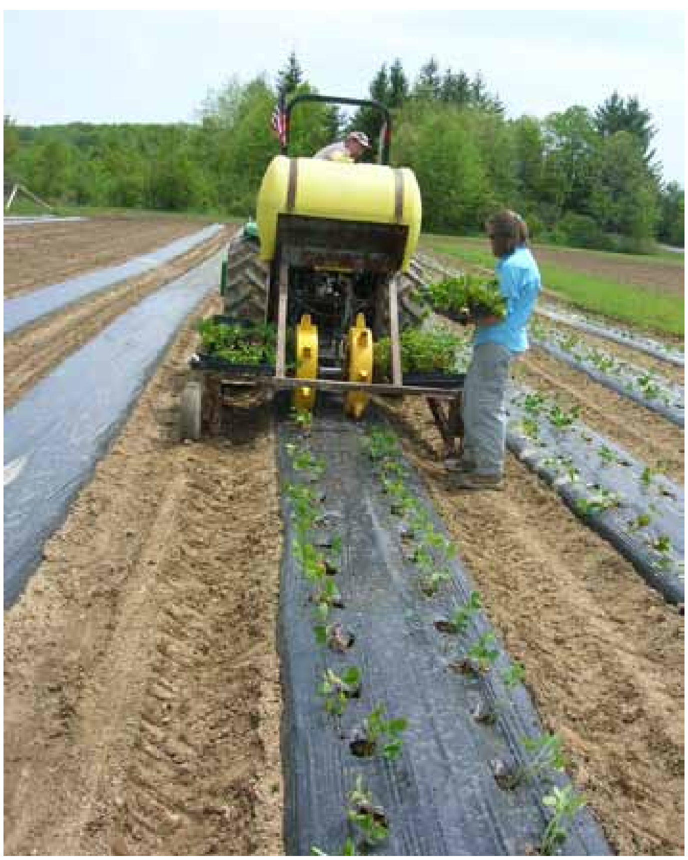


Fig. 3.12 Planting plugs using a water wheel planter.

Fig. 3.13 Strawberry plug planted with water wheel planter.

Spacing

Managing the plant density in a plasticulture planting is accomplished by changing not only the spacing between beds, but also the spacing on each bed. More plants produce more fruit; however, at some point the planting will become too dense, and cause less air flow and increased disease incidence. Double rows on each bed are typically used. Plants should be 12 inches apart within each of the double rows and placed in a staggered pattern. If plant vigor is high, due to either site or cultivar, growers may wish to increase in-row spacings to 16 inches apart. Although little research has been conducted regarding plant spacings for everbearers in the East, some vigorous cultivars such as Evie 2 may increase vegetative growth in response to wider spacings, but not produce more fruit. (See Table 3.1 for plant populations per acre).

Table 3.1
Number of Strawberry Plants per Acre at Different Bed and In-row Spacing

	Bed spacing (distance from center of one bed to the center of the next)			
	5 feet	6 feet	7 feet	8 feet
In-row spacing*				
12 inches	17,424	14,520	12,446	10,890
14 inches	14,935	12,446	10,668	9,334
16 inches	13,068	10,890	9,334	8,168
18 inches	11,616	9,680	8,297	7,260
*Signifies spacing between plants within each row of a staggered double row.				

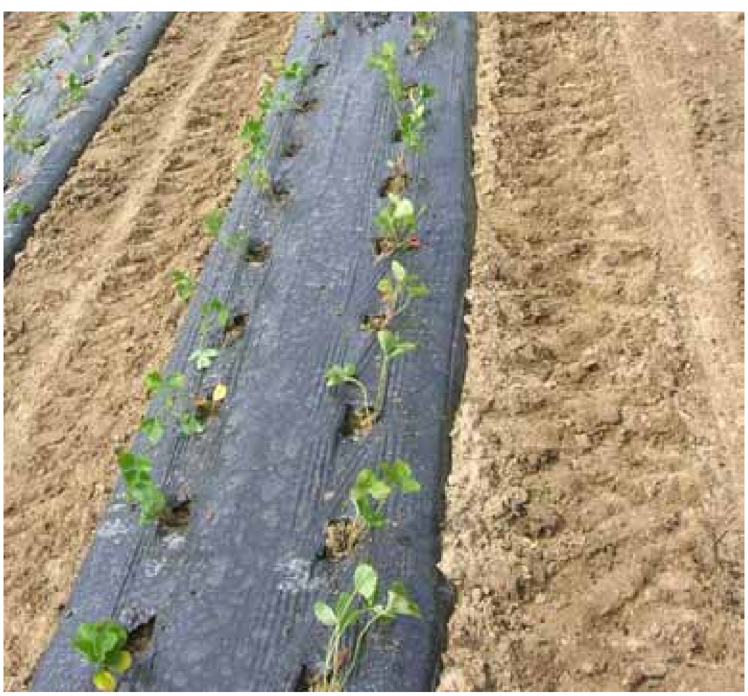


Fig. 3.14 Example of properly spaced strawberries on black plastic mulch.

Planting Care

After plants are in the ground, the main tasks consist of keeping the plants well-watered, fertilized and harvested. Insect and disease management is discussed separately in a later chapter.

Many factors affect the amount of water that should be applied, including the rate of plant growth, plant size and crop load, weather conditions, and soil type. 1-2 inches of water per week is generally sufficient, with lesser amounts applied early or late in the season, and higher amounts applied during warm spells and when the crop load is heavy. Example calculations are provided in Table 3.2 Irrigation that will allow growers to calculate the length of time that the system needs to be operated to apply 1 inch of water, and flow rate (gallons of water per minute) from the drip tape emitters. If the required flow rate is higher than the flow rate the grower's water source can actually provide, the grower will need to divide the irrigation area into zones and water them at different times.

The producer must monitor the plants during periods of high temperatures and high yields, and determine when additional water is needed. Irrigation should be administered at frequent enough intervals to keep the moisture supply even. In the following example, running the irrigation for 2-3 times per week is reasonable.

Table 3.2 Irrigation Example

Irrigation Calculating Needed Source Flow Rate and Irrigation Time

Assumptions:

- 1 acre of strawberries
- Beds are on 6-foot centers that are 30 inches wide
- 1 drip tape per raised bed
- Drip tape with a flow rate of 0.45 gallons per 100 ft per minute (a common flow rate) if the irrigation system is operated in the recommended pressure range of 10-12 psi.
- 1 acre-inch of water (the amount of water it takes to cover 1 acre with 1 inch) is equivalent to 27,154 gallons.

Step 1: Determine how much drip tape is needed in the grower's field.

The amount of drip tape in 1 acre can be calculated by dividing the number of square feet in 1 acre (43,560) by the bed spacing.

43,560 sq ft per acre / 6 ft = 7,250 ft of row, and thus 7,250 ft of tape

Step 2: Determine the delivery rate for the length of drip tape.

7,250 ft. of row X 0.45 gallons per 100 ft per minute = 33 gallons per minute

Step 3: Determine the number of zones needed.

If the source flow rate is at least the assumed 0.45 gallons per 100 ft per minute, water the entire field (allow for the fact that some water will be lost through leaks).

If the source flow rate is less than the assumed 0.45 gallons per 100 ft per minute, divide the flow rate of the trickle tape by the source flow rate, and round up to the next highest number to determine the number of zones.

For example, if in Step 2, 33 gallon per minute was needed and the source well produces 12 gallons per minute, 33/12 = 2.75 zones, which would be rounded up to 3 zones.

Step 4: Calculate the amount of water needed to deliver 1 inch to 100 ft. of row.

If beds are 30 inches (2.5 ft) wide, the area watered by 100 ft of drip tape is 250 sq ft Therefore:

$$\frac{27{,}154 \text{ gallons}}{\text{acre}} \times \frac{250 \text{ sq ft}}{100 \text{ ft of tape}} \times \frac{1 \text{ acre}}{43{,}560 \text{ sq ft}} = 156 \text{ gallons/100 ft of tape}$$

Step 5: Calculate how long the irrigation must run to apply 1 inch.

156 gallons per 100 ft ÷ by 0.45 gallons per 100 ft per minute = 346 minutes or 5.8 hours to apply 1 inch of water over a bed 30 inches wide.

Thus, for each inch of water to be applied to the area or a zone, the irrigation must be run for 5.8 hours after the lines are filled.

Given the information in the preceding discussion and the understanding that a fertilization program should be customized for each operation, Table 3.3 contains a sample fertilization program for spring planted annual everbearing strawberries. From Table 3.3, it can be determined that a small sized planting of everbearing strawberries require small amounts of fertilizer per 1,000 plants. It is recommended that growers have a small scale such as a postal scale for weighing accurate amounts of granular and soluble fertilizers.

Table 3.3 Fertilizer Example

Fertilization Example for Annual Spring-Planted Everbearing Strawberries

Assumptions

- Plug plants are planted in early May.
- Fruit production starts on June 15 and ends on September 30.
- 1 acre is planted with an expected yield of 20,000 pounds of fruit.

Crop Requirements per Acre

For this example, nitrogen amounts are based on current recommendations, and phosphorus and potassium amounts are based on results of a hypothetical soil test.

90 lb of Nitrogen (N) – Split Application
60 lb preplant incorporated
30 lb applied through the drip irrigation system.

53 lb of phosphate (P_2O_5)
71 lb of potash (K_2O)

A portion of these nutrients are applied through the drip system, with the remaining amounts preplant incorporated.

Vegetative Growth — first 6 Weeks

2 lb of N/acre is applied each week, half as 20-20-20 and half as calcium nitrate. Additional P2O5 and K2O as included in the fertilizer sources are also applied.

20-20-20

To provide 1 lb of N/week, 5 pounds of 20-20-20 is used per week per acre (1 ÷ .20)

6 weeks X 5 lb of 20-20-20 provides 6 lb of N, 6 lb of P_2O_5 and 6 pounds of K_2O

Calcium Nitrate (15.5-0-0)

1 lb N/week divided by .155 = 6.5 lb of calcium nitrate per week per acre

6 weeks X 6.5 lb of Calcium Nitrate provides 6 lb of N

(continued)

Fruiting Period - 16 weeks

1 lb of N/acre is applied each week. In order to provide the large amounts of potassium used during fruit ripening, a 9-15-30 soluble fertilizer is used as the nutrient source.

9-15-30

To provide 1 lb of N/week, 11 pounds of 9-15-30 is used per week per acre (1 ÷ .09)

16 weeks X 11 lb pounds of 9-15-30 provides 16 lb of N, 26.4 lb of P_2O_5, and 52.8 lb of K_2O

The nutrients that will be provided by soluble fertilizer during the vegetative and fruiting periods are:

28 lb of N
32 lb of P_2O_5
59 lb of K_2O

Refresher: The recommended amount of nutrients per acre was 90 lb of N, 53 lb of P2O5, and 71 lb of K2O

The remaining amount of nutrients to be provided is

62 lb of N
21 lb of P_2O_5
12 lb of K_2O

These nutrients will be applied preplant incorporated.

Providing the Remaining Nutrients — Preplant Incorporated

19-19-19 is a common fertilizer found at most agriculture dealers, so it can be used as the starting point for the preplant incorporated fertilizer. Start with the nutrient needed in the smallest quantity, in this case K_2O.

To apply 12 pounds of K_2O, 64 pounds of 19-19-19 (12.2 ÷ 0.19) is needed. This also applies 12 pounds of N and P_2O_5, which require an additional:

50 pounds of N
9 pounds of P_2O_5

This can be applied as 109 pounds of urea (46-0-0) and 19 pounds of triple superphosphate (0-44-0). To calculate:

50 pounds of N ÷ 0.46 = 109 pounds of urea

9 pounds of P2O5 ÷ 0.44 = 20 pounds of triple superphosphate

(continued)

Summary of Fertilization Plan

Preplant incorporated per acre
- 109 lb of urea (46-0-0)
- 20 lb of triple superphosphate (0-46-0)
- 64 lb of 19-19-19

Fertigation through drip irrigation per acre
- Weeks 1-6:
- 5 lb 20-20-20 per week/acre
- 6 lb of Calcium Nitrate per week/acre

- Weeks 7-22:
- 11 lb of 9-15-30 per acre/week

Rates for smaller plots or multiple zone systems—based on 15,000 plants per acre
Divide the fertilizer rates on the per acre bases according to the size (% of an acre) or number of plants.

Example 1 – 1000 plants

1,000 plants divided by 15,000 plants/acre = .067 acre or 6.7 % of an acre

Multiply each amount by .067.

Preplant incorporated per acre
- 7.3 lb of urea (46-0-0)
- 1.3 lb of triple superphosphate (0-46-0)
- 4.3 lb of 19-19-19

Fertigation through drip irrigation per acre
- Weeks 1-6:
- 0.34 lb (5.4 oz) of 20-20-20 per week/acre
- 0.44 lb (7.0 oz) of calcium nitrate per week/acre

- Weeks 7-22:
- 0.74 lb (11.8 oz) of 9-15-30 per acre/week

Weed Management

In the plasticulture system, when effective pre-plant weed control is established, the greatest concern for weed control will be the bare soil areas between the rows of plastic. Although weeds growing between the rows are not competing with the strawberries for water or nutrients, they reduce air flow which results in problems with plant diseases. This makes harvesting more difficult, and increases seed banks for future years and also may provide habitat for harmful insects. Weed growth between rows can be controlled in a number of ways. Chemical herbicides can be applied to the soil between the rows after the plastic is laid. Straw and other organic mulches also can be effective. Growers must apply 2-4 inches of material to sufficiently block light and prevent weed growth. Mowing or weed-whacking also can control weed growth; however, significant labor and care must be taken to prevent damage to the plastic. Planting low growing grasses or legumes is another option for weed control; however, the grower must establish a good early stand before weed growth occurs. Unfortunately, some legume crops also may attract insects such as tarnished plant bugs.

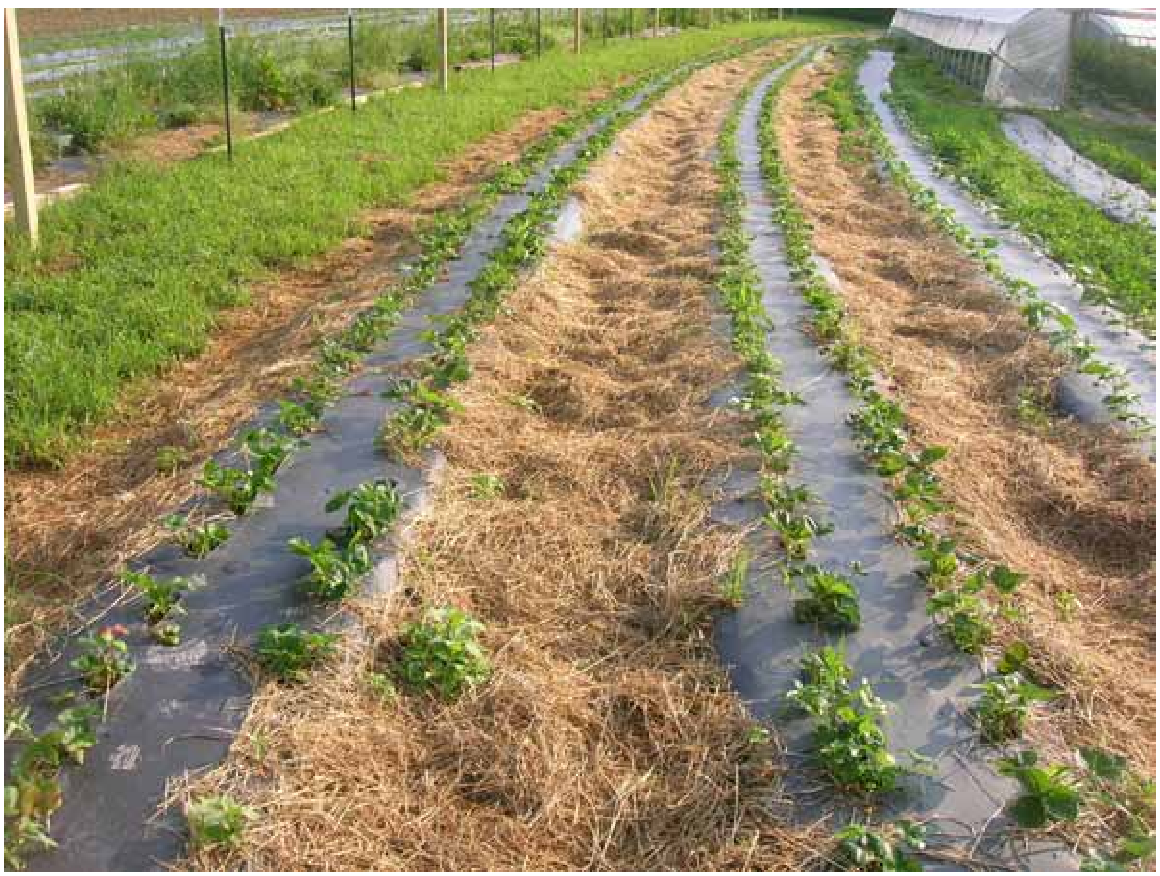


Fig. 3.15 Straw used as a weed barrier mulch between rows.

Harvest and Postharvest Care

The majority of everbearing strawberry harvesting is completed by the grower, with berries sold on-site at a farmstand or at farmer's markets. At this time, "Pick-your-own" production of everbearing strawberries is limited. Some growers report a difference in consumer acceptance in different circumstances. Consumers who are familiar with traditional harvest seasons for various types of fruit may be less accepting of "off-season" strawberries and may be ready to sample other traditional crops later in the summer and fall. In situations where berries can be marketed to a cross-section of consumers, such as at farmer's markets, sales may fare better. In any event, having sufficient labor to keep fruit well-picked is a necessity.

Since everbearing strawberries can produce fruit over a period of months, conditions at harvest time will vary greatly. When possible, harvest in the morning or evening when internal fruit temperatures are the lowest. Fruit is usually field-sorted, which is facilitated greatly by having "metal stands" or tables to hold picking trays. Fruit should be placed in shallow containers no deeper than 4 inches and should not be allowed to sit in the direct sun after harvest. Fruit quality is superior when the strawberries are harvested at least 3 times per week; daily harvest may be required for the best quality and highest marketable yield. Fruit should be picked slightly unripe if the grower plans to ship the fruit. Labor required for frequent harvest may present some difficulty. The price that can be obtained for the fruit must be sufficiently high to cover labor costs.

Once the fruit is harvested it must be stored in a cool location. If the fruit is held longer than 24 hours, it should be cooled to 32-33°F and kept at 90 % humidity. Growers should not place the fruit in a standard refrigerator because the air movement will remove moisture from the fruit. The best method to cool very small volumes of fruit is to place a couple inches of ice in the bottom of an ice chest, then place a board on top of the ice, and finally place the containers of strawberries on top of the board. Growers should not remove the containers from the ice chest until sold or transferred to another container. Fruit removed from cold storage will "sweat" which will cause fruit to deteriorate quickly.

A Second Growing Year

In areas with a short growing season and other areas selected by growers, a second (or perhaps third) growing season may be coaxed out of a plasticulture everbearing strawberry bed. Growers should be aware that disease and insect pests typically will increase over time. Generally, in cooler climates, especially with suitable varieties, the second year production will be higher than first year production. The first crop of the second year will have the largest fruit. Plants will be larger, which can make picking difficult and significantly increase disease. It is very likely that fruit size will decrease after the first harvest cycle in the second year. Also, vigorous plants may be difficult to manage.

In Chapter 1, the less intense winter dormancy of everbearing cultivars was discussed. Unfortunately, very few actions can change this natural weakness, except using standard straw or floating row cover protection in the field. Everbearers are typically a little more susceptible to winter injury than Mid-Atlantic June-bearing varieties, but are not quite as susceptible as some Florida varieties. Some varieties (e.g. Evie 2) can develop enough hardiness to survive Quebec winters.

Primarily, winter mulching is completed to maintain strawberry crowns and roots at a temperature of approximately 32˚F. Straw usually keeps the plants colder, while floating row cover allows enough light through to maintain a healthy leaf surface. All other factors being equal for the June-bearers (especially the mulch removal date), the straw mulched plants will ripen later. The additional "healthy leaf" time for photosynthesis under floating row cover will strengthen the plant and should result in a larger spring yield. Photosynthesis measurements indicate that initially the row covered plants use the reduced light under cover with relative efficiency. After 4 weeks, the heavy shade, cold temperatures (and frost), and shortening day-lengths gradually impact the photosynthetic mechanism and photosynthesis in plants in December; this occurrence may be less significant in the northeastern United States and Mid-West. Photosynthesis does not occur to any extent on red or yellow leaves. Therefore, leaves can resume functioning even after experiencing temperatures in the lower 20˚F's, provided that adequate acclimation is given. After leaf temperatures are in the teens, there is no reason to protect the leaves from the cold; however, crowns will continue to need protection.

For floating row covers in June-bearers, the goal is to prolong photosynthesis as long as possible in order to increase the strength of the plants; another aspect of the goal is to protect the crown and roots from cold injury. For everbearers, a June or spring crop may be desirable, but it is not the sum total of production. A small spring crop may be more desirable because it allows larger or earlier mid-summer crops. Given the lighter dormancy of everbearers, and the fact that temperatures under row covers can become very warm and potentially delay onset of cold hardiness, it may prove effective to increase the management of row covers for everbearers. Although the University of Maryland Extension is not aware of any work that has been conducted in this area, it may be advisable and more advantageous to delay the use of covers to allow earlier frosting of the everbearer leaves and greater cold acclimation. To further reduce the growth of everbearers, the removal of the covers during December warm spells is recommended more for everbearers than June-bearers—which should be deeper in dormancy. In any case, the amount and timing of the spring crop for everbearers, as well as June-bearers, can be altered somewhat by winter protection management. In general, floating row covers are an additional requirement for winter protection because they reduce wind desiccation.

For additional protection in very cold locations (USDA Hardiness Zones 5b and colder), straw mulch applied when soil temperatures at a 4-inch depth under the row covers drop to 40˚F has been utilized successfully. However, keeping the straw mulch on the plastic mulch is difficult without using a row cover. In these locations, removing the row cover, placing the straw, and replacing the row cover over the straw to keep it in place has worked quite well. Once the plants are covered with straw, the plant no longer receives any sunlight to form branch crowns or flower buds. Therefore, this technique is only recommended for marginally cold sites. Next, the straw should be removed from the beds and placed in the walkways as soon as the plants resume growth (or soil temperatures reach 40˚F at 4 inches deep), and the row covers alone pulled back. Row covers should be removed as soon as the plants begin to bloom. The plants must be covered again if frost is forecast.

For everbearers, spring frost protection is not as critical as for June-bearers, primarily because the spring crop does not comprise the entirety of annual production. Either 1-2 layers of row covers can be used, depending on anticipated low temperatures, or overhead irrigation if needed. The topic of frost protection is discussed in detail in the *Mid-Atlantic Berry Guide for Commercial Growers*.

Fig. 3.16 Fruit on second year Albion plants in late May in Garrett County, Maryland.

Chapter 4
Alternative Cultural Systems for Growing Everbearers: an Overview

Everbearing strawberries can be grown in a plethora of growing systems. While the vast majority of the everbearing strawberries around the world are grown by in-ground raised-bed plasticulture production methods, which were discussed in detail in Chapter 3, this chapter explores and explains other potential methods borrowed from June-bearer production and observations around the world.

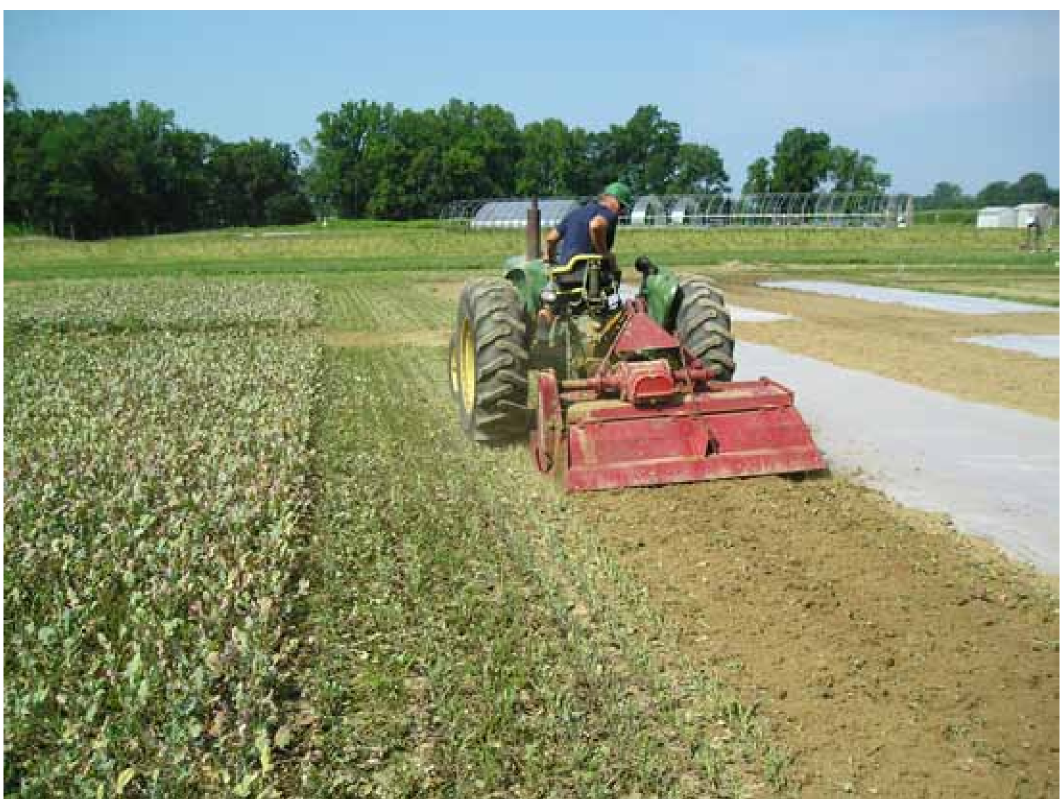
Matted Row Traditional System

Everbearing strawberries can be grown in traditional matted row systems using the similar production practices to June-bearers. Matted rows have advantages, including plant costs that are roughly two-thirds or less. Bare ground makes it easier to renovate plants, although in a more limited way than with June-bearers, either by tossing some soil around the crown to stimulate summer root growth and/or by trimming leaves in the second year before the hot summer months. Matted rows rely on new runners each year; therefore, it's unnecessary for growers to worry about plants becoming too complex and growing too many crowns. Each year, the renovation should be designed to eliminate mother plants from previous years. Older varieties of everbearers did not originally produce sufficient runners to fill in matted row beds; also, they were too expensive to propagate. Modern everbearers, runners, and the price of nursery-grown dormant everbearer plants have dropped nearly to that of June-bearer plants. Newer everbearing cultivars can create a matted row in suitable locations.

There are several issues which make it difficult to grow everbearers in matted rows or planting systems that take advantage of runnering when planted at low densities. A primary concern is weed control, with similar concerns to June-bearers grown in matted rows. Since fruit is picked the first year, the grower must be mindful of herbicide pre-harvest interval period restrictions or mechanical tillage must be faithfully practiced with precision and patience.

The phase-out of methyl bromide and growing interest in organic/sustainable approaches to strawberry production has led to the exploration of alternatives to fumigation for controlling weeds and soil-borne pathogens. In the past, soil solarization (tarping newly tilled soil for 4 weeks to cause the soil to superheat or "pasteurize") and rotation with Brassicas (rape, mustard and broccoli) that produce natural fumigant chemicals (isothiocyanates) and allelopathic plants such as rye have been explored as possible soil fumigants and weed control methods. None of these methods alone were as effective and long-lasting as fumigation; however, an integrated approach using a combination of these methods may prove promising. During the last 5 years of testing in Colorado and Maryland, the incorporation of spring-planted Brassicas was followed immediately with clear or black plastic tarp solarization for 4 weeks. This approach has shown promise for weed control. Incorporation and tarping are completed during mid to late summer (typically August 1), and certainly before seed set in the Brassica. In most cases, where the tarping was completed on moist soil, the use of Dwarf Essex rapeseed or Caliente mustard (20 lbs seed per acre) and solarization resulted in a reduction of the weed seedbank. This manifests itself as lower weed germination the following spring.

On the Eastern Shore of Maryland, the reduction of spring weed biomass was over 80%. Whereas most of this research was conducted with clear plastic tarps, another practical approach is to use a plastic mulch layer with black plastic immediately after the rapeseed is incorporated into the soil. The effectiveness of the procedure in other areas and during other years is not guaranteed; however, there are residual herbicides and other fumigants available. If tilled-under rape is followed by immediate solarization, the use of biofumigation may not be expensive—primarily it would be comprised of the cost of the seeds, plastic, and tillage.



Brassica *crop being rototilled for soil Sterilization, note the plastic tarps on the right which are being used for soil solarization.*

Oddly, everbearing strawberries create their own weed problem. Modern everbearers fruit in the same year, if planted during the spring. Unlike June-bearers, seed is continuously produced by everbearing plants, which means either fruit picking or flower removal is recommended. Leaving the fruit on the plant weakens the plant and encourages seed production. Strawberry seeds may germinate and grow. Juvenile seedling strawberries runner faster than adult cultivars and fill the matted row. Juveniles may not be everbearers and generally produce inferior fruit. If they are available at a reasonable price, tissue culture produced everbearers do not produce a lot of flowers for the first 15 weeks out of culture. Further, this period of non-flowering and rapid runnering can be extended with the use of the natural hormone, gibberellic acid.

Another factor in matted row establishment is the rooting of daughter plants. Either tilled bare ground must be exposed or expensive and time-consuming hand-pegging must be completed using straw or other mulch in order for the runners to root. Because runners must be established during the same time as fruit is being harvested, bare ground can result in dirty fruit that is more likely to have soft rot. The use of straw mulch and early establishment works well in regions that are too hot for mid-summer production. This requires early planting and ample care throughout the spring and summer. In late August, growers should apply straw to achieve a clean fall crop because the late runners cannot root through the straw are generally unproductive. The second year's crop will be more productive, assuming that the straw will remain in place and the slugs are controlled.

Another option for matted rows that does not rely on runners for a full bed, is placing plants closer together, with plants 5-10 inches apart in the row. An efficient planting design is a staggered double row with plants set 7 inches apart, offset 4 inches from center, with rows 4 feet or less apart. Runners must be removed throughout the first season and flowers should be removed for the first 6 weeks after planting. Growers should use 4 inches of clean straw to prevent large fluctuations in moisture availability and temperature. During the first year, everbearing strawberries fruit from mid-August through the first hard frost. Additionally, they produce three crops in subsequent years.

Plasticulture—Alternative Planting Times

Although plasticulture systems were discussed in Chapter 3, the focus was largely regarding spring plantings. Manipulating the planting time can accomplish fruit production at times of the year when local fruit can raise high prices.

Fall Planting

If plants are available and the risk and cost of winter protection can be unfailingly justified, fall plantings are more productive in regions with less than 2,500 growing degree days such as the Appalachian Highlands, Northern and Central New England, the Adirondacks, the Upper Peninsula of Michigan and surrounding Wisconsin (Door Co.), Minnesota, and the intermountain western plateaus and valleys above 6,000 to 7,000 feet elevation. Each of these areas is Zone 5 or lower; therefore, winter protection is a serious consideration.

Choosing a fall planting date may be complicated; however, the fall planting date should be early enough for plants to attain winter hardiness. During the fall, plug plant photosynthetic rates drop approximately 6 weeks after planting. This occurrence may indicate the plant's ability to acclimate to the lower metabolic rates of dormancy; therefore, at this point, the plant should be considered as established sufficiently for development of cold hardiness. If leaves are hardy at 22˚F, then the latest planting date should be no later than 3 weeks prior to the first frost; this will fall approximately around September 1 in most of the above-mentioned locations. This later planting date allows propagation of greater numbers of runners for plug plants and the possibility of larger or hardened fresh-dug plants. With later planting dates, the weather is usually cooler and the sun doesn't superheat the plastic as much. Floating row covers can be used to protect these plants, and should be available shortly after planting to protect against any frosts within 3 days of planting. Newly set fresh-dug or plug plants that are not pre-hardened are especially susceptible to frosts. Be advised that fresh-dug plants require 6-10 days overhead irrigation to prevent wilting during establishment and take an extra couple of weeks to catch up to plug plants. Therefore, plug plants may be preferable for later planting dates.

The case for earlier planting is one of safety and diversity of planting stock. Earlier set plants are more developed by the end of the season and able to withstand frost heaving and dehydration. If it takes an extra 2 weeks for a fresh-dug to catch up to a plug plant, then earlier planting dates will allow for use of both types of planting stock. Spring crop yield is theoretically higher because the size of the plant, and number of crowns, is considerably higher when plants are planted earlier. Growers should consider that early plantings, either as plugs or fresh-dugs (which may not be available at all) are more stressed from mid-summer heat. Although it is less of a problem with everbearers, summer planted (July to mid-August planted) material can produce runners.

If fresh-dug plants are available sufficiently early, the choice of whether to use fresh- dug versus plug plants often is further determined by the soil type and irrigation ability of the grower. If a grower has lighter soils and a ready supply of overhead irrigation, then the fresh-dugs are an option as the excess water does not flood the field. If the grower has a heavier soil and/or less water, plugs, or at the least removing the larger leaves from fresh-dugs to reduce transpiration, are the only options.

Typically, plug plants are not readily available or economical priced due to shipping to locations which can take advantage of fall plantings. A Northeast Sustainable Agriculture Research and Education (SARE)-funded project in Garrett County, Maryland, researched the feasibility of conducting on-farm propagation of plug plants for fall plantings. As conducted in Europe with everbearers, tissue culture mother plants were used to produce runners through the summer and then the runners are propagated for fall planting. These temporarily juvenile (quicker runnering, non-flowering) tissue culture plants were planted in plastic rain gutter with a thin layer of perlite on the bottom and peat/perlite potting soil with the "light" rate of slow release fertilizer in May. The plants were planted 8 inches apart and two of the rain gutters were placed back to back. The plants were treated with gibberellic acid and any flowers that developed were removed. The rain gutters were placed on stands about 6 feet off the ground with runners hanging over the sides. In August, the runners were removed and runner tips were placed in 50 cell trays. Due to typical hot dry weather and the fact that most farms would not have mist chambers, the newly planted tips were placed in a shady area and covered first with a layer of clear plastic and then with a light layer of translucent "floating" row cover. The plants were mist-watered daily.

Propagation of the plug plants takes about 4 weeks to establish a solidly rooted plug. After attempting to establish plug plants for 2 years, the farmer finally was able to create between 10-15 plugs per tissue culture plant. The cost to create the plugs was approximately $0.30 per plant compared with fresh-dug plants at $0.18 per plant. Plug plants planted in the fall had nearly 100 % survivability compared with fresh-dug plants at about 66 % survivability. As usual, the fresh-dug plants required overhead irrigation for 10 days. The plugs only required "watering in" by water wheel or overhead irrigation. The grower's production was lower than what was obtained by nurseries in Europe and the cost of the plug plants would be lower if production were to improve to 25-40 plugs per tissue culture plant. This is likely possible with a more experienced grower and more controlled conditions during runnering. Tunnel or greenhouse production in cooler areas and an earlier start in March should yield improvements.

In warmer areas, shading and cooling the propagation would be required; however, the grower can let the plants runner later in the year because the planting date is later.

On-farm plug production should only be considered if the grower has the time and expertise to complete this high-quality process.

Fig. 4.2 Producing runners in elevated gutters.

Summer Plantings

Mid-summer planting with dormant plants is a production practice in California. A fall crop may be too late for most production regions with less than 2,500 growing degree days and above 2,500 foot elevation. However, in warmer climates, growers may produce during the fall—either outdoors in the cooler pre-frost weather, or protected during frost events with floating row covers to extend production, or in tunnels. If everbearing or some June-bearing varieties (e.g. Festival) are planted early enough in mid-summer (July or August) by using plug plants produced from dormant plants, a late summer-initiated fall crop may be possible in October to December; particularly in areas along the southern coasts and lower elevation areas in the intermountain region of the west. When everbearers are used, it is advisable to remove flower trusses during hot weather. If that crop fails from early frost damage, the spring and summer crops in the following year will still be available.

Spring flowering of everbearer cultivars can be very early if forced; however, it usually occurs during the same season as June-bearing types. Because their dormancy is less intense, flowers sometimes grow through the winter, under conditions which are not favorable for photosynthesis. This results in poor anther development and symptoms of frost injury such as cat-facing and puckering. In general the *The Mid-Atlantic Berry Guide for Commercial Growers* recommendations for summer-planted June-bearers in a plasticulture system apply to everbearing culture.

Everbearing Production in High Tunnels

High tunnels are becoming popular and profitable around the world. Tunnel production for fresh market is a standard in Spain, the United Kingdom, Mexico, and other countries where price and production allow it. Where tunnels are used, rain damage is eliminated, pest severity is reduced, the crop is earlier, and weed control can be simplified. Yet, it may not be beneficial to use tunnels for summer production of everbearers in most sections of the United States. Certainly, mid-summer temperatures must be low enough (<85˚F) to keep the tunnels from overheating the plants. This limits the use of tunnels for summer strawberry production to a few regions in the United States: Mountain Appalachia, northern New England, the Upper Peninsula of Michigan, near the Great Lakes, and in the higher elevations of the Rocky Mountains. In most of the eastern United States, the use of tunnels to extend the season in the fall and early spring or winter is more appropriate than use for summer production. The high temperatures reached in high tunnels during the summer are not conducive to strawberry production, making the amount of fruit produced relatively low for the effort and cost.

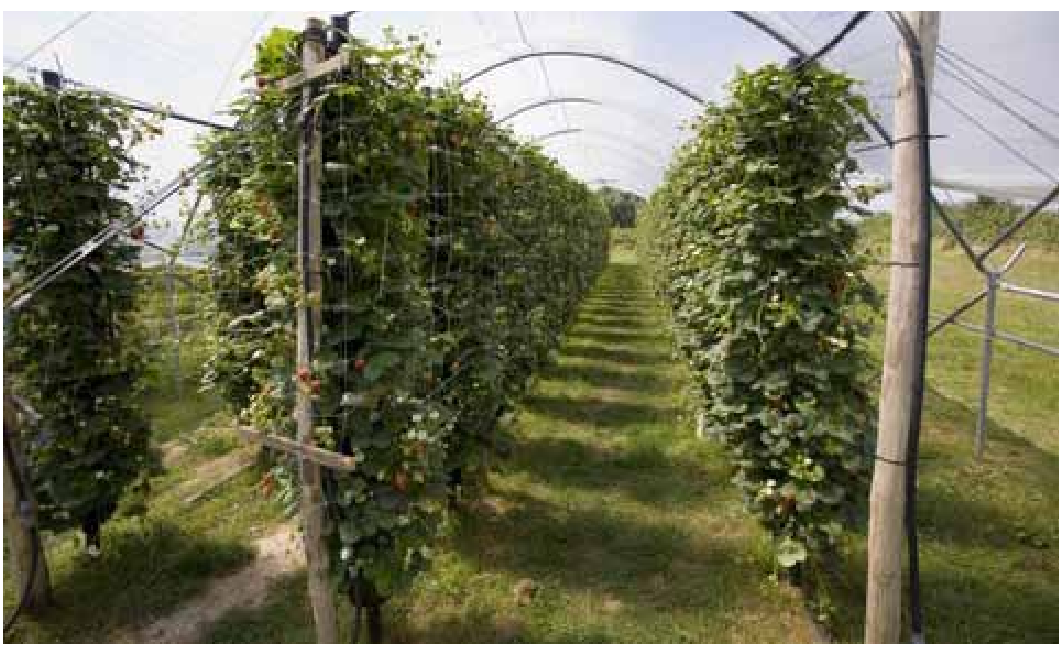


Fig. 4.4 Everbearing strawberries produced in a vertical system in high tunnels.

Fig. 4.3 Everbearing strawberries produced in high tunnels in the Netherlands.

Strawberries can be grown in high tunnels using production methods similar to those used for field production. Soil preparation and planting are completed for field production, with the exception that narrower beds and/or closer bed spacing can be used to allow more strawberry plants to fit in the tunnel. Plants should be well watered. Care during the spring is similar to that of field production, with the exception that pollinators may need to be introduced since resident pollinators are not likely to be active when the plants start to bloom. Bumble bees or mason bees have been used successfully for pollination, but care must be taken to keep temperatures within a range they can survive. Honey bees may be used, but they often become disoriented in the tunnel.

Disease and insect complexes are different in the tunnel than they are in the field. If the tunnel is kept covered, certain diseases such as gray mold and various leaf spots are likely less problematic. Powdery mildew; however, is likely to be a problem. Two-spotted spider mites are usually problematic, therefore monitoring should be continual from the time of planting onward. Predatory mites provide effective control when released while spider mite populations are still low (i.e., fewer than 20 mites on a few isolated leaves). When tunnels have been kept closed during the winter, it creates mild soil conditions, and soil-dwelling insects such as sowbugs and earwigs may build to high populations. On occasion, they become a fruit-feeding pest, causing losses of marketable fruit. Interpretation of which pesticides can be used in tunnels varies from state to state. In most cases, pesticides used in greenhouse production or pesticides that don't specify "field production use only" can be used. However, state regulations should be checked.

High Tunnels for Summer Production

In the mountains of Appalachia, at 2,600-foot elevation, spring-planted Evie 2 plug plants produced 1.5 pounds of fruit in a high tunnel the first year as part of a SARE study. The crop in a high tunnel fruits earlier, but field-grown plants produce higher yields during late summer. Throughout the growing season, the yields are the same. At the Appalachian study site, average yearly rainfall tops 50 inches. In the field, frequent precipitation may cause *Botrytis* and other fungi and prevent harvest of sound fruit, even with proper use of fungicides. Tunnels reduce this problem by eliminating fungal spread by rain splash. One grower had more sound fruit from a 20 x 60 foot tunnel than from Ð acre of field production. Significant additional income can be made from high tunnel production in markets where strawberries command $3.00 per pound and growers can produce 1.5 pounds of saleable fruit per plant. Consistent weekly production is also very important when wholesale marketing to retail outlets.

High tunnels also will allow the use of bare root plants in spring since soil preparation can be completed at any time inside of the tunnel. Planting bare root plants should be completed by the first of April or much earlier if possible every year. With the additional heat units from the high tunnel, an early planting of bare root plants will start producing at about the same time as outdoor plug plants planted later in the spring. A cost saving of approximately 66 % or $0.20 per plant will be achieved using bare root plant. While this cost savings does not justify the cost of the high tunnel, when combined with additional income from saleable fruit it will make using the tunnel more profitable.

Another factor to consider will be the type of high tunnel required for summer strawberry production. Typical four-season high tunnels cost $2.00 to $3.00 per square foot. Three-season field type high tunnels designed for rain protection are available for a little more than $1.00 per square foot. With these tunnels, the plastic would be placed during the early spring at planting time and removed during the fall. This type of tunnel provides rain protection, thus increasing the quality and quantity of fruit sold. With fruit prices as low as $2.00 per pound and total production at 1.5 pounds per plant, a 20 % increase in saleable yield would more than justify the cost of the tunnel, especially during rainy seasons when 50 % of strawberries from outside production are non-salable fruit.

Late Fall and Early Spring Production

In warmer climate areas high tunnels allow for late fall and early spring production. High tunnels can be used to protect against frost and provide additional heat units. Bare root plants planted during mid-summer will begin to produce fruit in the early fall. These plants will continue to produce until late fall. Growers must be ready to cover plants with floating row covers on nights where temperatures fall below 25˚F, or possibly higher if the tunnel is not well-sealed.

With respect to the occurrence of overwintering, plants will greatly benefit from floating row covers or rolled styrofoam covered with white plastic—which is typical of nursery stock protection. The tunnel is usually closed in—that is, the ends are sealed and the sides are rolled down. If the temperature in the tunnel exceeds 60˚F, venting should be initiated, either by rolling the sides up or operating a fan. Most often, this treatment keeps the leaves alive and potentially photosynthetically active through the winter as well as ensures a large crop in the spring. In the United Kingdom, a floating row cover over raspberry plants in tunnels offers about 12˚F of protection. In Garrett County, Maryland, styrofoam sheets (✥ inch thick) with a R-value of 1, covered with 2 mil polyethylene plastic, protected plants in unheated greenhouses up to 18˚F, even after several sub-freezing days outdoors. If foam sheets are removed for the day and replaced at night, about 25˚F of frost protection is afforded if the day is sunny and the night is wind-free.

Spring production should begin as much as 2-3 weeks before outdoors fall planted or overwintered plants. This early production will be in high demand. Growers must remain aware of the outside temperature during the night due to the fact that the row covers may need to be replaced in order to prevent the loss of flowers.

Greenhouse Production

Considerable work regarding greenhouse strawberry production has taken place at Cornell University and at USDA's Appalachian Fruit Research Station in Kearneysville, West Virginia. Production costs for greenhouse strawberry production will be fairly high. At Cornell, a break-even price of $3.00 per pint was calculated. Growers interested in additional information should consult the *The Mid-Atlantic Berry Guide for Commercial Growers* or other sources of information). Briefly described, in this system, dormant crowns are planted in pots and grown outdoors until late fall, and then cold stored at 28-30˚F. Both June-bearing and everbearer types have been used successfully. June-bearing varieties are moved into the greenhouse at intervals for fruit production 10-13 weeks later. Everbearers can be treated the same way, which will produce a "spring crop." Using this system with lower light levels may cause some everbearing varieties to develop "spring" fruit that is misshapen. Supplemental light and a day-night temperature regime of 75-55˚F are used. Everbearers will continue to fruit and should be left to produce until fruit becomes small. Plants must remain simple (only a few crown branches), this can occur by keeping the crowns exposed—that is, growers should not put more soil around the plant to stimulate new roots. Nutrients are provided both in the mix and with a complete fertilizer solution that supplies 50-100 parts per million of nitrogen. Bumble bees were found to work well as pollinators.

Powdery mildew and two-spotted spider mites are likely to be problems, as in high tunnel production. In addition, other insects that are common greenhouse pests (e.g. fungus gnats and thrips) and gray mold have proven problematic. Vigilant scouting and early release of biocontrol agents can prevent many of these pests from developing into significant problems.

Vertical Systems, Table Top, and Soilless Culture

The relatively high return, the high cost of tunnels and greenhouses, and the small size of strawberry plants make off-season everbearing strawberries an interesting plant to grow using a variety of unconventional systems. However, as of this writing, the use of vertical, table top, or other specialized systems for strawberry production in the eastern United States has yet to show significant advantages overproduction in the ground. Yields are not higher than conventional systems and conventional systems achieve yields more easily. The intensive management required for unconventional systems presents a challenge for many growers, and the high cost of these systems is often difficult to recoup. The University of Maryland Extension team recommends that growers (with the exception of the most experienced everbearer growers) should first gain experience and success with the crop using a conventional plasticulture system before considering more specialized systems.

Fig. 4.5 Container production in the Netherlands.

Out-of-the ground or elevated systems take advantage of high planting densities to produce high yields in small spaces. These systems lower the cost of the greenhouse or high tunnel per pound of fruit produced, but add to costs per pound of fruit produced as well as increase management. Out-of-the-ground systems require effective management and the ability to capitalize on higher out-of-season prices. Everbearers are an excellent selection for summer production; however, June-bearers (especially those bred to fruit in winter like Florida's "Strawberry Festival") are a strong choice for heated winter production. Out-of-ground systems features may include:

- Most out-of-ground systems begin with some form of soil-less growing media.
- Coir, peat, and rice hull mixes and various homemade blends of peat, leaf mold, perlite (less common) and compost/manure (<30%) are used as a growing media soil.
- Water management in containers is critical. A flexible watering system should be designed that is capable of delivering water at frequent intervals during hot weather and high fruit production.
- The main consideration for the media is to select media that will both hold water and nutrients and drain off excess water. For standard housing gutters, a thin-layer (1/2-inch deep) of perlite on the bottom of the gutter to drain the water from the mix is recommended.
- 3/8-inch holes are drilled every 12 inches to allow drainage if gutters are used.

Everbearing plantings are expected to continue producing fruit for 6-11 months. Planting dates are usually off-phase with outside planting dates to maximize fruit price. Dormant plants can be used, but in Europe, plug plants are used. Slow-release fertilizer is commonly used with fertigation through trickle irrigation. Winter lighting is not common. However, if winter lighting is used, growers should implement the following rule:

1 % increase in light = 1 % increase in yield

Out-of-ground strawberry plants are commonly "shallow planted;" this includes planting horizontally in the Netherlands. In addition, plants are never "renovated" in terms of adding soil to the top of the pot. The goal of these cultural techniques is to prevent strawberry plants from branching while in elevated culture. When the crown elongates in the air, with a small 1-2-branched bonsai-looking mini-tree, no new roots will exist on the "high" crown. The lack of new roots will help keep the plant simple, because the root-formed hormones that cause branching (cytokinins) will be produced in limited quantities. This prevents the plant from becoming too complex, which causes fruit size to decline in later months of production. From Mexico, to Washington State, the United Kingdom, Spain, and the Netherlands—all elevated strawberry plants look similar after 6 months—simple and vigorous.

Above-Ground Horizontal Systems

Horizontal systems can be at ground level or as elevated structures. Elevated structures at breast- or neck-height are attractive, because picking fruit is easier. Growing containers can be bags, gutters, or pots. The containers should be deep and wide enough to provide for sufficient root growth and water retention; however, plants may require multiple waterings per day and constant fertilization. Unlike field plantings, there is limited ability to store water and nutrients. Galvanized metal should be avoided because it may cause high concentrations of zinc.

Fig. 4.6 Elevated horizontal system in a high tunnel in the United Kingdom.

Fig. 4.7 Suspended horizontal hydroponic system being used in Mexico, note the boxes below the troughs that were used for a previous crop of peppers and tomatoes.

Vertical Systems

The two major considerations for vertical systems are water management and planting orientation. Vertical system water management may become problematic if water is applied to a vertical rigid plastic tube or column filled with soil. The water will move to the bottom and the top of the vertical column will be dry. This occurrence can be corrected in two ways in vertical systems: (1) restrictors are placed in the vertical tube that runs down the column; or (2) the vertical column is segmented to prevent water from flowing down to the bottom of the column.

Above: Fig. 4.8 Vertical growing system using rigid PVC plastic columns.

Left: Fig. 4.9 Hydroponic vertical growing system.

too close together, causing a difference in light and heat accumulation. Because the light and heat are from the same source (the sun), knowing the temperature stratification, which can be taken with a meat type thermometer is a simple way to plan spacing. Spacing varies, based on latitudes, time of year, sun angle, and number of cloudless days. Most of these systems have set numbers of plants per area (i.e. linear or square feet), therefore spacing the columns is a method that can maximize yield per tunnel or greenhouse. Finally, the rule of thumb is the farther north the planting the taller the trellis. Incident light on tall trellises in north latitudes occurs at a lower angle and shading is not as severe—an aspect that has some utility when designing the height and dimensions of vertical systems. A grower's perception with regards to excessive shading may prove helpful.

TIP:
To determine the highest potential yields per square foot (or acre) of floor, compare yield-per-plant records with plant number-per-square foot of floor.

Summary

Strawberry plants, due to their size and architecture can be grown in as many innovative cultural systems as possible or as many as financial feasible. Because of their high productivity and ability to produce throughout the year, everbearing strawberry plants allow many of these systems to become profitable. Growers should gain some experience with growing everbearing strawberries with a conventional system before taking on a large scale alternative system.

Chapter 5
Pests

Everbearing strawberries are affected by many of the same pests as June-bearing plants. However, the plants produce fruit during the entire growing season, instead of only in spring and early summer. Therefore, the fruit-feeding pests usually present during late summer or whose populations build as the summer progresses, can be more problematic for everbearers than June-bearers. A second consideration is that pest control products must have a pre-harvest interval that is shorter than the interval between harvests. Because fruit is harvested for a long period of time, pesticide use is limited to certain products. If products with a long pre-harvest interval must be used during harvest, any fruit picked within the pre-harvest interval must be discarded in order to avoid the possibility of fruit having higher levels of pesticide residues than are allowed. Finally, plants are already stressed from producing fruit. Additional stress from insects or diseases can cause great reductions in plant health and future fruit production. This guide does not attempt to address all possible pest issues that may arise—only those that are likely to become problems for everbearer production. Additional references are listed under "Additional Reading" for growers who require additional information regarding pests and pest management. Appendix A lists fungicides available for the diseases discussed in this guide; Appendix B lists the insecticides, miticides, and molluscides.

Diseases

Root Rots (including *Verticillium* wilt, Red stele, *Fusarium, Rhizoctonia*, and *Pythium* root rots)

Many root-rotting diseases that affect strawberries can be avoided with annual planting of strawberries if effective cultural practices are followed. To avoid diseases that affect the root system, an important cultural practice is to rotate crops. Strawberries should not be planted in fields that have had strawberries, solanaceous crops (e.g. tomatoes and potatoes, or other fruit crops) for at least 5 years; 10 years is a preferable time scenario. Promising selections for preceding crops that

Fig. 5.1 Plant with root rot.

have few pests in common with strawberries are cereal grains and corn (be aware of possible herbicide residue carryover). Also, strawberries should only be planted in well-drained soil; however, raised beds are helpful for marginal situations. For soilless culture, especially those with minimal amount of peat moss or other organic composts, the severity of black root rotting organisms, especially *Pythium*, is much greater than in soil. The use of *Trichoderma* has been helpful for combating this problem, which can result in plant collapse for susceptible varieties.

Gray Mold (*Botrytis*)

Gray mold, which causes a gray fuzzy coating on affected fruit when sporulating, is caused by the fungus *Botrytis cinerea*. The fungus lives as a parasite and saprophyte on decaying plant debris. The fungus will invade the developing fruit and cause it to rot when it is time for the fruit to ripen. The fungus can cause a blossom blight, especially during prolonged periods of wet overcast days, and this fungus also can turn the caps brown. Protecting the fruit begins with applying fungicides during bloom; at this time the fungus invades the blossoms and grows into tissues that will form the fruit, only to become apparent later. Ripe fruit also can be infected from other fruit or leaves, particularly when the fruit is in contact with plant material that is already infected. Cultural practices that remove disease inoculums will help; such practices include continuous fruit harvest, removal of decaying fruit from the field, and removal of dead foliage from the field. Any practice that encourages drying the foliage and fruit, such as keeping the field weeded and row middles short, will minimize the periods of wetness that are required for fungal spore germination. Several fungicides are effective for controlling gray mold; however, the fungicide selected should have a short pre-harvest interval. These fungicides should be applied according to the label, but may require repeated treatments due to the extended flowering season of the everbearers. Growers must ensure that they rotate among fungicides with different modes of action, designated by different Fungicide Resistance Action Committee (FRAC) codes in order to avoid building up strains of the fungus with resistance to certain pesticide chemistries.

Anthracnose (*Colletotrichum* spp.)

Several species of fungi that are closely related can cause a variety of symptoms including fruit rot, crown rot, leaf spots, or lesions on runners and petioles. Most commonly observed and problematic for everbearing plants is anthracnose fruit rot, which first appears as tan sunken fruit lesions on the fruit that then turn dark brown or black in color. Salmon-colored spores also may eventually appear on these lesions.

At this time, no everbearer cultivars have been noted to have resistance, though degree of susceptibility varies (see cultivar descriptions). This disease is a warm weather disease; thus, fungicides are not needed until temperatures warm, usually about the time that the first fruit are formed. Cultural practices are important, and should be primarily concerned with obtaining clean plants from a reputable supplier and avoiding cultivars that are extremely susceptible. If anthracnose is noticed in a certain area in the field, growers must be aware that inoculum can be distributed to other plants on equipment or the harvester's hands. The disease cannot exist without living plant tissue; thus, rototilling under plants in badly infected areas or rows can help stop spread of the disease. Several effective fungicides that control anthracnose are in existence; however, several of them are in the strobilurin chemical class (FRAC code 11) which is at risk for development of fungal resistance. Thus, growers must strictly follow manufacturer recommendations for usage as listed on the package. If lesions are noted, apply effective labeled fungicides every 7-10 days until temperatures cool and symptoms lessen.

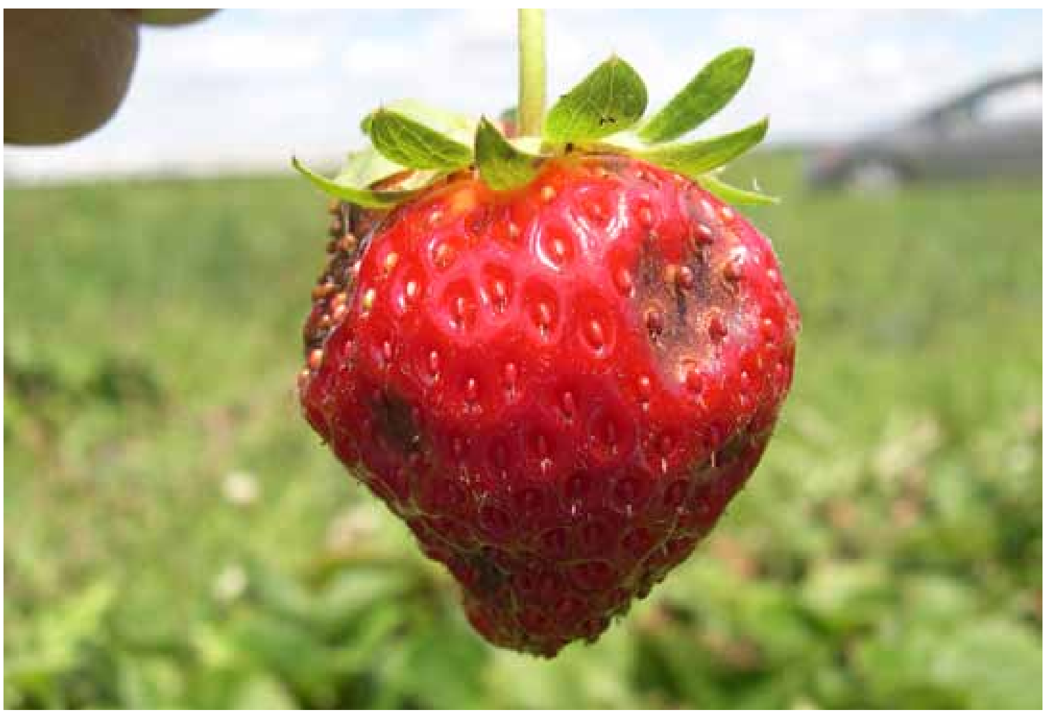


Fig. 5.2 Strawberry fruit with Anthracnose.

Powdery Mildew

The powdery mildew fungus, *Sphaerotheca macularis*, must have living tissue to survive. The mycelium causes the upper leaf surface to have a white dusty upper appearance, the leaf underside develop a purple coloration which can cause the leaves to curl inward. Infected fruit has a white powdery appearance and seeds may fall off easily when the surface is rubbed. Though uncommon, flower parts also may be invaded, thus causing fruit to either fail to form or to be severely misshapen. Among everbearers, the cultivar Seascape is notoriously susceptible. Conditions of warm temperatures, high humidity, and low rainfall can commonly cause powdery mildew issues to become worse. Thus, disease incidence is frequently higher in high tunnels than it is in the field. Cultural controls consist of using practices that minimize humidity levels in the planting such as keeping field plantings weeded and high tunnels well ventilated. Several effective fungicides exist, but are at risk for development of fungal strains resistant to them. Thus, precautions should be taken in their use such as rotating among different chemical classes and minimizing the number of sprays applied to the extent possible.

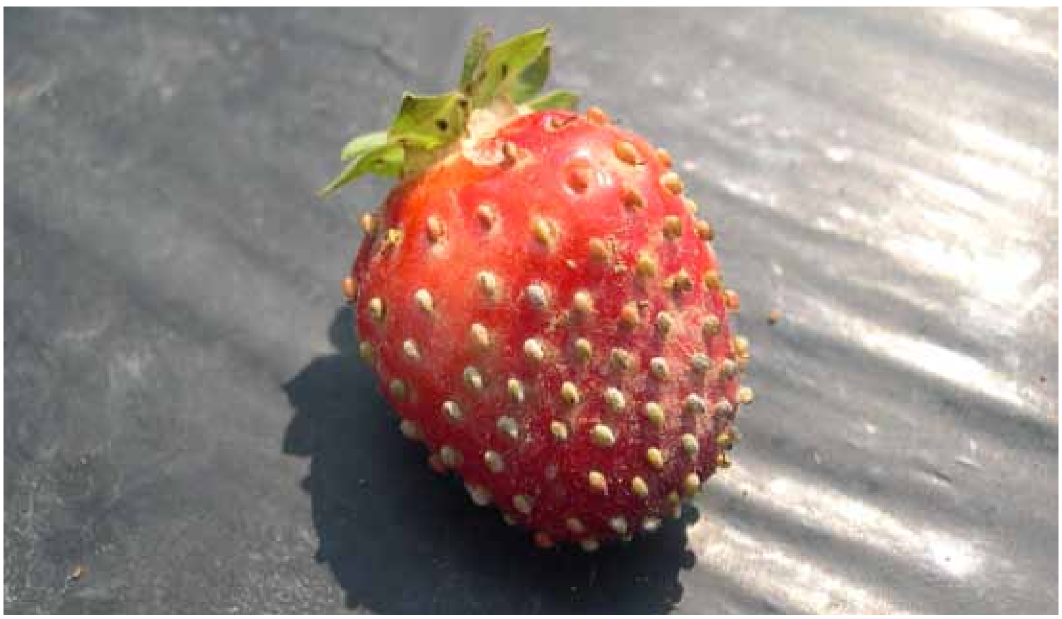


Fig. 5.3 Powdery Mildew on fruit.

Fungal Leaf Spots (Common Leaf Spot, Leaf Scorch, and Leaf Blight)

Various leaf spots can be problematic for everbearing cultivars, especially late in the season when growth of the foliage slows and damp cool conditions are conducive to fungal sporulation. Differences in appearance between the three most common ones are that common leaf spots are usually small (Ð inch- ✣ inch across), and begin having a white center which may fall out as the spot ages. Spots resulting from leaf scorch usually range from dark red to purple, and are a solid color, and may coalesce to occupy large areas of the leaf that die and turn dry. This is probably the most common leaf spot disease for everbearing cultivars in the Northeast, and can be confused with bacterial leaf spot (see below). Leaf blight begins as a V-shaped discolored wedge with the widest part at the edge of the leaf, and usually is not very problematic within a planting. All of these diseases also can infect the caps making fruit much less attractive. Any cultural practices that reduce periods of leaf wetness and humidity will be helpful. Several fungicides are labeled for control of the various leaf spots.

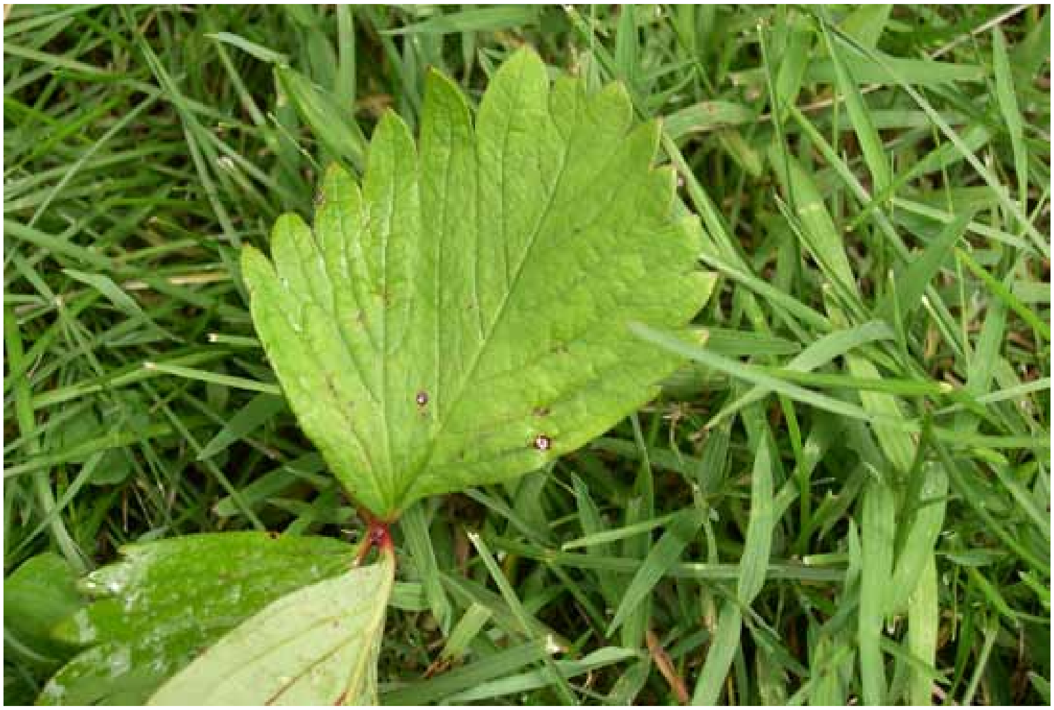


Fig. 5.4 Common Leaf Spot.

Bacterial (Angular) Leaf Spot

This disease is worse under cold wet conditions, such as when overhead irrigation has been used in the spring for frost protection, or in fall after temperatures cool. Bacterial leaf spots can be differentiated from fungal leaf spots because the leaves, when viewed have light shining through them as well as a clear or "windowpane" appearance between the small veins of the leaf. Since the spots are contained between these small veins at first, they have an angular (blocky) appearance rather than being circular as with common leaf spot and leaf scorch. The fruit caps, when remaining wet, will have a blackened appearance, but as they dry, the cap color becomes brown. All everbearing cultivars tested in the East have moderate to considerable susceptibility to this disease. Since this disease is bacterial and not fungal, conventional fungicides have no effect, though copper sprays may be helpful. Growers should watch for signs of phytotoxicity such as leaf discoloration (purple spots), and discontinue use if phytotoxicity symptoms become apparent.

Fig. 5.5 Angular Leaf Spot on the calyx.

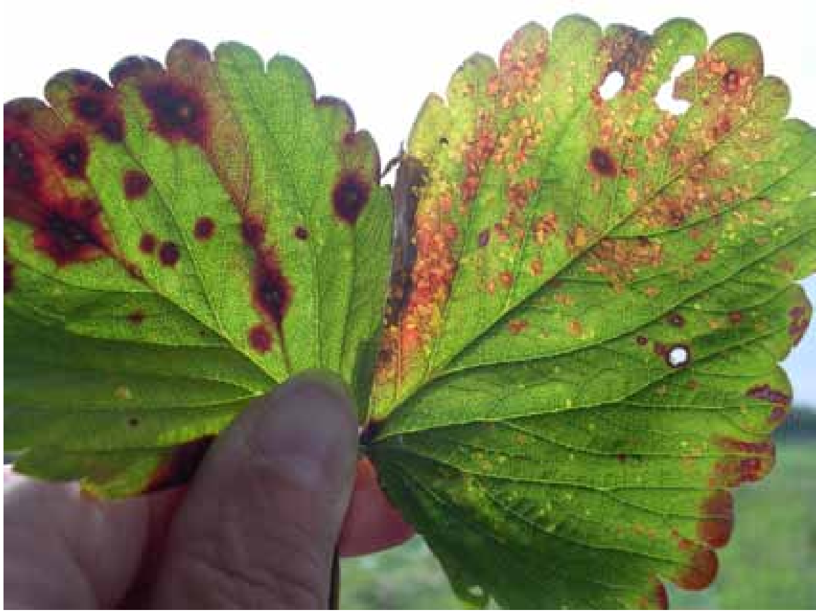


Fig. 5.7 Leaf Scorch compared to Angular Leaf Spot with light from the back.

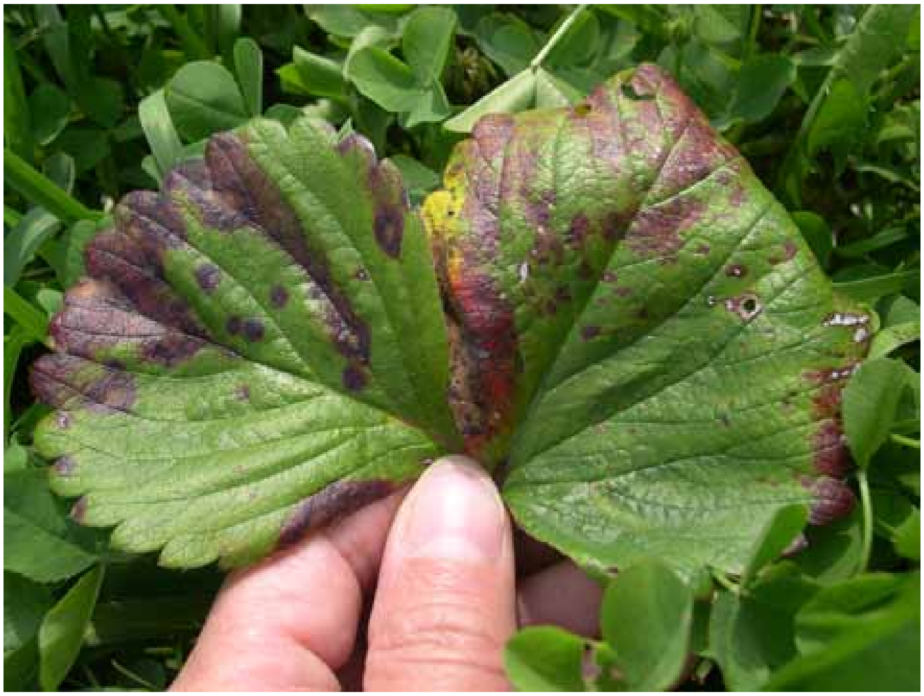


Fig. 5.6 Leaf Scorch versus Angular Leaf Spot.

Insects, Mites, and Mollusks

Tarnished Plant Bug (*Lygus lineolaris*)

The adult tarnished plant bug is a small (approximately ✥ inch long) and brownish colored insect with a "brassy" appearance. It has a distinct 'V' shaped marking on the center of its back behind its head. The tarnished plant bug is a true bug with piercing-sucking mouth parts; it feeds upon a variety of weeds and cultivated crops. Several generations occur each year with adults and nymphs present from April until frost in the fall. Because of multiple generations occurring within one season, populations continue to build as the season progresses. Therefore, damage to everbearing cultivars can be even more extensive than with June-bearers. Tarnished plant bug adults overwinter in protected areas. They return to strawberry fields during the spring to feed upon all sorts of plant parts, but the most noticeable damage occurs when tarnished plant bugs feed upon the seeds and fruit tissue of developing berries. Distortion of the berries known as "cat-facing" occurs when feeding by the bug destroys developing embryos in the seeds; this prevents the growth of the fruit tissue underneath and surrounding the damaged seeds and results in severely deformed fruit. When feeding occurs on the tips of the young berries, the tips do not expand, which causes an injury referred to as "button berry." Seeds are clumped at the tips of these small, underdeveloped fruits.

Tarnished plant bugs can be difficult to control with regard to everbearing strawberries due to the extended bloom time. Mowing nearby weedy areas or hayfields may heighten the problem, because displaced plant bugs relocate into strawberry fields. Growers should review Appendix B for pesticides used to control tarnished plant bugs.

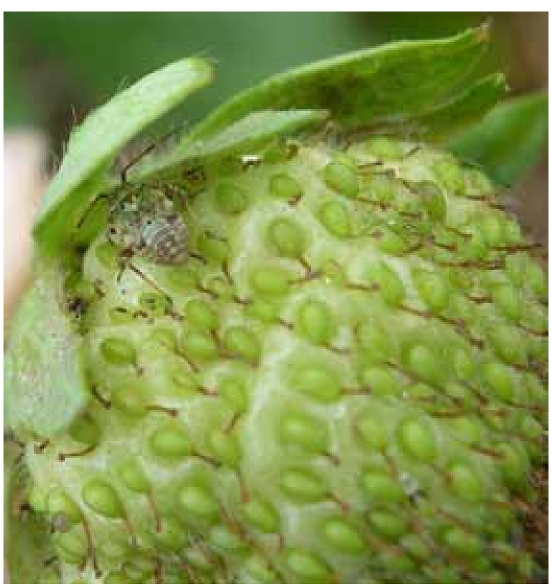


Fig. 5.8 Late instar Tarnished Plant Bug nymph.

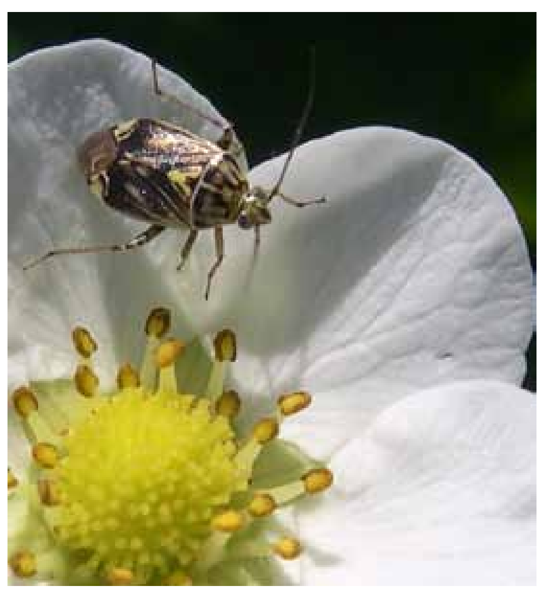


Fig. 5.9 Adult Tarnished Plant Bug on strawberry bloom.

Potato Leafhopper (*Empoasca fabae*)

Fig. 5.10 Potato Leafhopper.

The potato leafhopper does not overwinter in the Northeast; instead it is carried into the area annually by winds travelling from the South. Leafhoppers typically become a larger problem during early to mid-summer and often infest strawberry fields after nearby hay fields have been harvested. Low populations of leafhoppers may not be noticed because they are tiny (1/8 inch long) and adults quickly disperse when disturbed. The light green nymphs, however, will remain on the leaf undersides and move sideways to escape detection. As populations increase, downward cupping and yellowing of leaves will become apparent. Symptoms are often most severe on small or stressed plants. Leafhopper populations must be controlled if populations are causing damage; otherwise, plants will be stunted and late season production will be limited. Several insecticides are labeled for use on strawberries, however, because the insect moves in from outside the region, no cultural controls are effective in decreasing populations.

Strawberry Sap Beetle (*Stelidota germinate*)

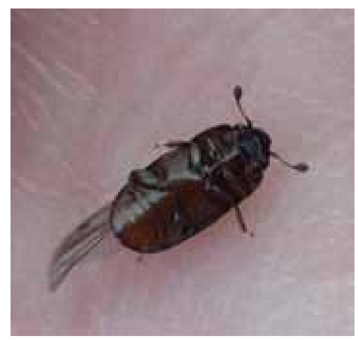


Fig. 5.11 Sap Beetle.

Adult sap beetles are small, dark brown oval-shaped beetles that are about Ð inch long. They chew small holes into ripe fruit, often where the fruit touches the ground. In addition to the obvious damage which appears similar to slug feeding, sap beetles also introduce fruit rot organisms as they feed. Sap beetles can be difficult to locate, except when populations are large, because they tend to quickly drop to the ground and find a hiding place when disturbed.

Adult sap beetles emerge during the spring from protected overwintering sites in wooded areas. These beetles are attracted to overripe decaying berries on which they will feed and deposit their eggs. After the eggs hatch, larvae feed upon the strawberry fruit for approximately 1 1/2 weeks after which they burrow into the soil and pupate. Adults emerge 2-3 weeks later and begin the cycle over again.

The best way to manage sap beetle populations is through cultural control. Because sap beetles are highly attracted to decaying fruit, good sanitation practices are essential. Growers should pick berries before they become overripe and destroy unmarketable fruit rather than letting it lay in the field. It is recommended that growers do not plant more strawberries than can be picked in a timely manner. Pesticides may be used, but they will not provide as much control as proper cultural control.

Slugs

Slugs are mollusks that can cause considerable damage to strawberries; they create small, moderately deep holes in the ripening fruit. Slugs often feed under the cap on strawberries, but holes can be found almost anywhere on the berry. These pests usually feed at night, but they also may feed during the day if the weather is overcast and rainy. The shiny slime trails left behind on plants or on the ground are tell-tale signs of their activity.

Slugs range in color from gray to cream and may even be spotted. Depending on the species, slugs may be 1/4–8 inches long. Slugs prefer to hide in cool damp locations during the day. Their eggs are laid in clusters in cracks in the soil, in compost piles, and under layers of wet leaves. Slugs reach adult size in 3-12 months and can live for several years.

Slug populations can be controlled through a variety of methods, but habitat modification and chemical control strategies are most efficient for moderate to large scale producers. Slug control should be initiated with the elimination of favorable habitats for slugs to hide and breed. This can be achieved by removing excessive mulch, piles of junk, boards or rocks, and compost piles from close proximity to the field. Slugs can be collected in the morning by traps constructed of wet boards, shingles, or overturned flower pots set the previous evening. Commercially produced baits are readily available and provide effective control. Iron phosphate baits degrade readily into the soil, and unlike products containing metaldehyde, can be used near the plants.

Japanese Beetle adults (*Popillia japonica*)

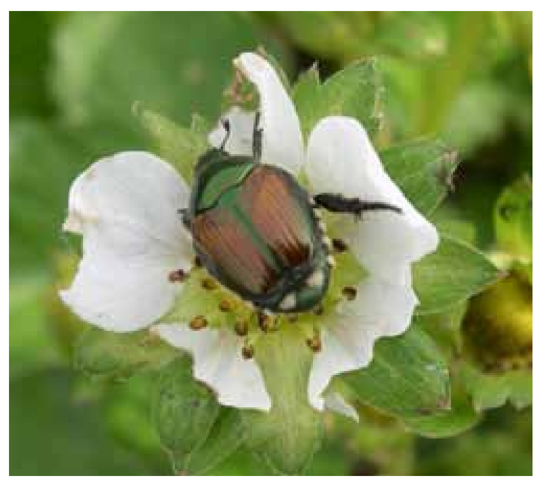


Fig. 5.12 Japanese Beetle on strawberry flower.

Japanese beetle adults are 1/2 inch long metallic green to bronze insects. Typically, Japanese beetle adults are not significant pests with regards to June-bearing strawberries, unless they are feeding upon the foliage late in the season in large numbers. However, with regards to everbearers, Japanese beetle adults may feed upon the fruit causing holes. In addition, these pests may fall into harvest containers where they crawl to the bottom of the container to hide. Only one generation appears each year, but not all adults emerge at the same time and they can fly great distances. Individual adults live for 30-45 days; therefore, control measures may be required for up to 2 months. Larvae feed on roots during late summer and late fall. No cultural methods have proven very effective. Because Japanese beetle pheromones (scent attractants) used in many traps attract even more Japanese beetles to the field, hand-picking or treating the field when the first beetles appear may assist in minimizing numbers in the field. Few insecticides are labeled for use against Japanese beetles for strawberries, and the most effective one has a long pre-harvest interval that may preclude its use during harvest.

Spider Mites (*Tetranychus* spp.)

Spider mites are not insects, but are related to ticks and spiders. They have 8 legs and are about the size of a period. The two-spotted spider mite is the species most commonly found on strawberries. Spider mites typically feed upon the underside of leaves. Mites suck the contents out of individual plant cells, thus removing chlorophyll and causing the leaves to have a stippled appearance. When mite populations are high, leaves develop a bronze color from the feeding damage and webbing may be present on the underside of the leaves. Mites sometimes inject toxins as they feed, which may cause leaf distortion as well as discoloration. Mite feeding interferes with plant physiology and may result in stunting, reduced yield, and plant death. Because mites are difficult to see and they feed on the underside of leaves, they may be easily overlooked until significant damage has occurred. Increases in spider mite populations frequently follow the use of broad-spectrum insecticides, which often harm beneficial insect or mite populations that had been keeping the spider mite population under control.

Due to short generation times, spider mite populations can build quickly especially under warm, dry conditions. New plantings can become infested by mites carried by the wind from other locations; therefore it is very important for growers to monitor their plants on a weekly basis to detect the presence of spider mites using a 10X hand lens. Plasticulture plantings that will be carried to the following year should be checked for spider mites before straw or row covers are applied in the fall, because the warm protected environment will allow mite populations to increase over the winter.

Spider mite infestations can be suppressed through several methods. When two-spotted mite populations are low, predatory mites can be purchased commercially and released. Miticides should be applied if more than 25 % of inspected leaves have mites, a sharp population rise is noticed, or if plant health worsens. Thorough spray coverage of leaf undersides is critical in order for chemical control applications to be effective. Therefore, high spray volume and high spray pressure must be used to achieve good coverage. Miticides with different modes of action should be alternated during subsequent applications in order to prevent resistance from occurring. (See Appendix B for miticide listings). Miticides differ in their effect on beneficial mite populations and in which stage of pest mite populations they control. Growers must read the label or other sources of information for additional details.

Cyclamen mite (*Steneotarsonemus pallidus*)

Cyclamen mites are not visible with less than 20X magnification. The symptoms from their feeding—small distorted off-color new leaves—are probably always noticed before the mites are discovered. If populations continue to build, plants will become unproductive. Cyclamen mites may arrive in the field on nursery plants, and can be spread on workers hands or implements. Predatory mites can assist in control. Labeled miticides are listed in Appendix B.

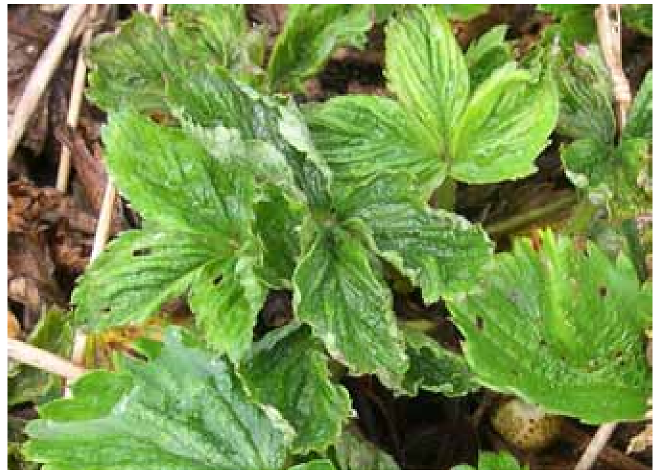


Fig. 5.13 Cyclamen mite damage on strawberry foliage.

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Fungicides for Strawberry Disease and Insect Control

Note: The recommendations below are correct to the best of the University of Maryland Extension's knowledge. Other formulations with the same active ingredient as some of the products listed below may exist and may or may not be labeled for the same uses. Always consult the label before making pesticide applications. Information is current as of October 1, 2009. See text discussions on diseases for information on timing of application for effectiveness. Some materials are at high risk for development of resistant fungal strains. Be sure to follow label for limitations on use beyond pre-harvest and reentry intervals and follow recommendations for rotations with other pesticide chemistries.

	Common name	Product example and labeled rate per acre	FRAC Codea	Efficacy	Days to Harvest	Reentry Interval
Botrytis fruit rot (gray mold)	fenhexamid	Elevate 50WDG, 1.5 lb	17	+++b	0	12 hr
	captan + fenhexamid	Captevate 68WDG, 3.5-5.25 lb	M + 17	+++	0	24 hr
	pyraclostrobin + boscalid	Pristinea, 18.5–23 oz	11 + 7	+++	0	12 hr
	pyrimethanil	Scala SC, 18 oz	9	+++	1	12 hr
	cyprodinil + fludioxinil	Switch 62.5WDG, 11–14 oz	9 + 12	++	0	12 hr
	captan	Captec 4L, 3 qt	M	++	0	24 hr
	thiram	Thiram 75WDG, 4.4 lb	M	++	3	24 hr
	thiophanate-methyl + captan	Topsin M 70WSB, 0.5 lb plus Captec 4L, 1.5 qt	M	++	1	24 hr
Anthracnose fruit rot	pyraclostrobin + boscalid	Pristinea, 18.5–23 oz	11 + 7	+++	0	12 hr
	pyraclostrobin	Cabrio EG, 12–14 oz	11	+++	0	12 hr
	azoxystrobin	Aboundb, 6.2–15.4 oz	11	++	0	4 hr
	captan + fenhexamid	Captevate 68WDG, 5.25 lb	M + 17	++	0	24 hr
	cyprodinil + fludioxinil	Switch 62.5WDG, 11–14 oz	9 + 12	++	0	12 hr
	captan	Captan 50W, 6 lb	M	++	0	24 hr
Powdery mildew	myclobutanil	Rally 40W, 2.5-5.0 oz	3	+++	0	24 hr
	triflumizole	Procure 50WS, 4–8 oz	3	+++	1	12 hr
	propiconazole	Orbit, 4 fl oz	3	+++	0	12 hr
	pyraclostrobin	Cabrio EG, 12–14 oz	11	+++	0	12 hr
	pyraclostrobin + boscalid	Pristinea, 18.5–23 oz	11 + 7	+++	0	12 hr
	quinoxyfen	Quintec, 4–6 fl oz	13	+++	1	12 hr
	azoxystrobin	Aboundb, 6.2–15.4 oz	11	++	0	4 hr
Common Leaf Spot						
	myclobutanil	Rally 40W , 2.5–5.0 oz	3	+++	0	24 hr
	pyraclostrobin + boscalid	Pristinea, 18.5–23 oz	11 + 7	+++	0	12 hr
	captan	Captec 4L, 3 qt	M	++	0	24 hr
	pyraclostrobin	Cabrio EG, 12–14 oz	11	++	0	12 hr
Angular Leaf Spot	copper hydroxide	Kocide 2000, 1.5-2.25 lb	M	+	0	24 hr

a. FRAC codes refer to fungicide classifications as designated by the Fungicide Resistance Action Committee. Different numbers denote different modes of action.
b. + = slightly effective, ++ = moderately effective, and +++ = very effective.

Insecticides, Miticides, and Molluscides for Strawberry Pest Control

Note: The recommendations below are correct to the best of the University of Maryland Extension's knowledge. Other formulations with the same active ingredient as some of the products listed below may exist and may or may not be labeled for the same uses. Always consult the label before making pesticide applications. Information is current as of October 1, 2009. See text discussions for information on timing of application for effectiveness. Some materials are at high risk for development of resistant pest strains. Be sure to follow label for limitations on use beyond pre-harvest and reentry intervals and follow recommendations for rotations with other pesticide chemistries.

	Common name	Product example and labeled rate per acre	IRAC Codea	Efficacy	Days to Harvest	Reentry Interval
Tarnished Plant Bug	bifenthrin	Brigade WSB, 6.4-32 oz	3	+++ b	0	12 hr
	acetamiprid	Assail 70WP, 1.7-3.0 oz	4A	++	1	12 hr
	fenpropathrin	Danitol 2.4EC, 10.67 oz	3	+++	2	24 hr
	malathion	Malathion 57EC, 1.5-3.0 pt	1B	++	3	12 hr
	thiodan	Thionex 50WP, 2 lb	2A	+++	4	5 days
	carbaryl	Sevin 4F, 1.5-2 qt	1A	++	7	12 hr
Leafhoppers	malathion	Malathion 57EC, 1.5-3.0 pt	1B	++	3	12 hr
	carbaryl	Sevin 4F, 1-2 qt	1A	++	7	12 hr
	thiamethoxam	Actara, 1.5-3.0 oz	4A	+++	3	12 hr
	acetamiprid	Assail 70WP, 0.8-1.7 oz	4A	−c	1	12 hr
	insecticidal soap	M-Pede, 2.0% solution	−c	−c	0	12 hr
Sap Beetles	bifenthrin	Brigade WSB, 6.4-32 oz	3	++	0	12 hr
	fenpropathrin	Danitol 2.4EC, 16-21.3 oz	3	++	2	24 hr
	acetamiprid	Assail 70WP, 1.7-3.0 oz	4A	+	1	12 hr
Slugs	metaldehyde	Deadline Bullets, 10-40 lb	–	+++	nsd	12 hr
	iron phosphate	Sluggo, 20-44 lb	–	+++	ns	0 hr
Japanese Beetle Adults	acetamiprid	Assail 70WP, 1.7-3.0 oz	4A	++	1	12 hr
	pyrethrins	Pyganic EC 1.4 II, 1-4 pt	3	+	0	12 hr
	carbaryl	Sevin 4F, 1-2 qt	1A	+++	7	12 hr
Spider mites (adults or adults plus immatures)	bifenazate	Acramite 50WS, 0.75-1.0 lbs	un	+++	1	12 hr
	acequinocyl	Kanemite 15SC, 21-31 fl oz	20	+++	1	12 hr
	spiromesifen	Oberon 2SC, 12-16 fl oz	23	+++	3	12 hr
	abamectin	Agri-Mek 0.15EC, 16 oz (3)	6	++	3	12 hr
	fenbutatin oxide	Vendex 50WP, 1.5-2.0 lb (1)	12B	++	1	48 hr
	dicofole	Kelthane 50W, 1-2 lb (3)e	un	++	3	48 hr
Spider mites (immatures)	hexythiazox	Savey 50DF, 6 oz	10	+++	3	12 hr
	etoxazole	Zeal, 2-3 oz	10	+++	1	12 hr
Cyclamen	thiodan	Thionex 50WP, 4 lb (4)	2A	+++	4	5 days
Mites	dicofol	Kelthane 50W, 3.0-4.0 lb	un	++	3	48 hr

a. IRAC codes refer to pesticide classifications as designated by the Insecticide Resistance Action Committee. Different numbers denote different modes of action.
b. + = slightly effective, ++ = moderately effective, and +++ = very effective.
c. Information is not available
d. A specific pre-harvest interval was not specified on the label.
e. Kelthane use is being discontinued. Growers may continue to use existing stocks for strawberries.