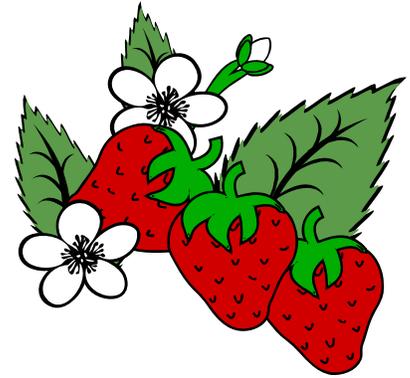


PERENNIAL STRAWBERRY PRODUCTION

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Throughout the colder regions of the world, strawberries are grown as perennials and fruited for several consecutive years. Cold temperatures and short days in fall and winter combine to promote a single flush of flowering and fruiting in late spring, and long daylengths in summer promote extensive stolon (runner) formation. Rather than attempt to remove these runners, perennial strawberry growers often encourage runnering by planting at low densities and allowing plants to establish "matted rows" the first growing season. Plant densities increase from about 7,000 per acre at planting to perhaps 100,000 or more by the end of the first growing season. In spring of the second growing season, the original mother plants plus their daughters flower and fruit. Matted rows typically produce yields of 12 - 15,000 lb/A, but as much as 25,000 lb/A, during late spring and early summer of the second and subsequent years with low initial costs and moderate risk. Yields and berry size tend to decline over time, so the planting is generally removed after three to five fruiting seasons. An alternative to the matted row is a "ribbon-row" high density planting system which produces some fruit in the planting year, and very high yields in the first fruiting year (up to 30,000 lb/A). Each of these will be discussed in detail.

Site Selection

Ideal sites for perennial strawberries are well-drained and have moderate to high organic matter (>2%). If soils are not well-drained, raised beds can be used or drainage installed. The soils should also be fertile and have a pH near 6.5; nutrients and lime are applied and incorporated prior to planting, following the results of a soil test. Sandy loams are ideal. In general, sites that produce good alfalfa crops tend to be good for strawberries.

Do not grow strawberries for 5 or more consecutive years on the same site without some type of crop rotation. The longer that strawberries are grown on a site, the greater the risk of root diseases. Also, herbicide carryover can impede the establishment of berry plants and can make berries more susceptible to root diseases. Certain matted row varieties are susceptible to verticillium wilt, so care must be used if following solanaceous crops. All sites should be tested for nematodes. Fumigation or cover cropping may be required if levels of root lesion or dagger nematodes are high.

The site should be near a water source, and if the crop is to be sold pick-your-own, near a major highway.

Site Preparation

A major step in site preparation is the elimination of perennial weeds. This is particularly important because few herbicides are labeled for use in berries, and their activity on perennial weeds is limited. Weeds cause a greater economic loss in berry crops than diseases and insects combined. In addition, weeds also encourage the establishment of other pest populations. Eliminating weeds the year before planting is much easier than controlling them later. Too many growers plant directly into a site in which perennial weeds were not eliminated the previous summer, and then spend the next several years trying to find the right combination of herbicides to undo the damage. Starting site preparation two or three years in advance will be rewarded in future years.

Rotation, coupled with the use of a broad-spectrum post-emergent herbicide the summer before planting, is an effective approach. Repeated cultivation or covering a site with black plastic for several months are also effective. Ideally, begin site preparation 2 or 3 years before the crop is planted to eliminate perennial weeds, especially if organic methods are to be used.

Fumigation at high rates will suppress weeds, although its use worldwide will likely be restricted because of environmental concerns, availability and expense. In some situations, nematodes, soil diseases, soil insects or intense weed pressure may justify fumigation. The soil should be friable, warm (>50F) and without decomposing plant material for fumigation to work properly. The best time to fumigate is late summer or early fall of the year prior to planting.

Test the soil for pH, potassium, phosphorus, magnesium, calcium and boron. Sample soil in a V-shape pattern within the field, collecting from at least 10 locations. The sample should represent the profile of the top 10 - 12 inches. Plow the site, add the recommended amount of nutrients, then disc. Because soil testing procedures are not standardized, follow the recommendations from the laboratory where the samples were analyzed. Do not use the test results from one laboratory and the sufficiency ranges from another.

Apply sufficient potassium, phosphorus, magnesium and calcium prior to planting to sustain the planting for its productive life, and supplement with other nutrients as required. It is difficult to make these nutrients available to plants when they are applied after planting.

It takes one year for lime to raise, and for sulfur to lower the soil pH, so it is necessary to apply these one year in advance of planting. Certain nutrients, like phosphorus, are very insoluble in water and move very slowly through the soil. It may take years for phosphorus applied to the soil surface to reach the root zone of

the plant and be taken up. For this reason it is imperative to apply a sufficient amount prior to planting and mix it into the root zone.

Animal manures and legumes offer a good source of slow-release nitrogen when incorporated prior to planting. Animal manures also contain significant amounts of potassium, phosphorus and calcium, but little magnesium and are a potential source of weed seeds. Manure applied to fields should be well-composted and worked into the soil prior to planting to minimize any risk of fruit contamination from pathogenic bacteria and to reduce weed seed germination. Supplemental magnesium may be required if manures are used to provide nutrients.

The irrigation system should be in place prior to planting because transplants require immediate watering. Any preemergent herbicide applied after transplanting will need to be watered in by rain or irrigation to be effective. For these reasons, the irrigation system should be operational prior to planting. Also, in early spring, the irrigation system can be a tool for frost protection. Many matted row growers are converting from overhead irrigation to drip irrigation. Drip irrigation requires less water, it can be used during harvest, and it reduces weed growth between rows.

Seeding a cover crop on the site the year before planting is an excellent way to improve soil structure, suppress weeds, and if the proper cover crop is grown, suppress nematode populations. Benefits of a cover crop are greatest when the soil is sandy and/or the soil organic matter content is low. Most cover crops grow under the same soil conditions as strawberries. Except for additional nitrogen (40 lb/A prior to seeding) and perhaps phosphorus, other amendments are not likely to be required.

Minimum seeding rates are used when the objective is to supply an acceptable stand for harvesting the grain or straw. But when a vigorous, dense stand is desired for weed suppression and organic matter, higher seeding rates are recommended.

Preplant cover crops are usually plowed under in the late fall or early spring prior to planting. Those with low nitrogen contents (grains and grasses) should be plowed under early in the fall to allow adequate time for decomposition, unless the soil and site are prone to erosion. Legumes contain more nitrogen and decompose quickly, so they can be turned under within a month of planting.

Establishing the Matted Row

Dormant transplants are planted between 12 and 24 inches apart in mid-spring (April – May), with 42 to 52 inches between rows (5,000 - 8,300 plants/A), on well-prepared soil. Ensuring that transplants are well-watered is critical for establishment. During the first year, runners fill in the gaps between plants to establish a matted row. The earlier that plants are set, the more runners that are produced. Later plantings are less successful because runnering decreases with

planting date. If one must plant in late spring, then the space between plants within the row must be reduced since fewer runners will be produced. Planting in early summer at wide spacings is often not successful because runner production is reduced, daughter plants do not produce enough leaves for flower bud production, dormant plants lose vigor after many months in storage, and the root system grows poorly when soil temperatures are too warm. Late plantings can be successful and result in fewer weed problems if higher densities are used (see ribbon rows).

Soon after planting, the crowns produce a few leaves and some flower buds emerge. These flowers are removed to encourage runnering and good bed establishment. Allowing fruit to mature on young transplants can reduce their vigor. About 4 weeks after planting, the strawberries are fertilized with about 30 - 60 lb/A of actual nitrogen to enhance establishment. Calcium nitrate is the fertilizer of choice in young plantings because the salt index is low. The width of each row is limited by cultivation to no more than 18 inches during the establishment year.

Weeds during the establishment year are the biggest challenge for perennial strawberry growers since there is much bare soil surface during the first year. A preemergent herbicide can be applied after the soil has settled around the roots of the plant, but the available number is very limited. Frequent, regular cultivation and hand-weeding during the establishment year will greatly increase the life of a strawberry planting. Early season weed growth is much more detrimental to strawberry plant growth than late summer weed competition.

Irrigate to maintain soil moisture levels above 50% water holding capacity to ensure optimum growth. Drip irrigation is being rapidly adopted by matted row growers, although overhead irrigation is still the norm. By late summer the beds should be well filled, with about four to six plants per foot of row. About 30 lb/A nitrogen is applied in late August to early September to ensure adequate fall growth. The choice of fertilizer is less important at this time. Urea, ammonium nitrate or calcium nitrate are used.

Plants begin to go dormant in late fall (mid to late November), and in cold climates, are covered with mulch to protect the crowns from extreme cold and desiccation. Three to six inches of straw over the plants is typical, and is applied once night temperatures reach the low 20s, usually late November or early December. One ton of straw provides about one inch of cover. Wheat and rye straw are best. Mulch is raked off in the early spring (March or April) and placed between the rows to provide a dry medium for the fruit to develop upon. Remove straw as soon as mid-March. Late straw removal decreases yield and delays flowering.

Row covers are commonly used to accelerate flowering and increase yields. Covers are applied in mid-March, or as soon as the straw is removed. It remains on the planting until flowering begins, then it is removed to allow bees and wind

to pollinate. (Fruit size is increased by about 15% with good bee activity.) Some growers keep the row covers next to the planting, and use them for frost protection on cold nights.

Flowers are susceptible to frost during the spring, and may be protected by the use of overhead irrigation, run continuously during periods of below freezing temperatures. Growers with drip irrigation can use row covers as an alternative to overhead irrigation for frost protection. If overhead irrigation is in place and row covers are still deployed, the irrigation can be used over the row covers to provide excellent frost protection with little water.

Flowering begins about 6 weeks after the onset of warmer temperatures. A well-managed planting has healthy, green leaves, few weeds in the planting, and a good straw alleyway for suppressing weeds and certain pathogens. The first fruit is ready for harvest about three to four weeks following full bloom. The harvest season lasts for about 2 - 3 weeks per variety, with early and late varieties providing about 5 weeks of total harvest. The first berries harvested are always the largest, and size decreases during the short picking season.

Following harvest, the beds are renovated. This is largely a thinning process to prevent overcrowding caused by the rooting of too many runner plants. As a first step, many growers apply 2,4-D to kill perennial broadleaf weeds in the row. After several days, leaves are mowed off the plants as a disease prevention measure, to aid in the penetration of miticides, and to allow the application of herbicides that would otherwise burn the leaves. Leaf removal is not essential, though, and can be detrimental if the root system is unhealthy or if the planting is under water stress.

After mowing, the plant row is narrowed to a 10 – 15 inch width with a disk harrow or rototiller. Since new roots are formed above older roots on the crown, plants benefit from an inch of soil over top of the crowns when rows are narrowed. Removing the side guards of a tiller is one way to mechanically throw soil over the rows. However, more than one inch of a soil covering can be detrimental.

Soon after mowing, the planting is fertilized and irrigated to stimulate growth of crowns and runners. Cultivation is used to maintain row width and control weeds during the summer and early fall. In autumn, beds are mulched as before, and fruiting occurs again the following spring. Beds generally are carried over for three to four fruiting years.

Unlike annual plasticulture strawberry production systems, a large number of varieties are used for perennial production. Because the season is so short, most growers use early, mid and late season varieties to extend the season for as long as possible. Common varieties are Earliglow, Northeaster, Annapolis, Honeoye, Kent, Allstar, Jewel, Raritan and Lateglow. Desirable traits are large fruit size, bright red color, flavor, productivity, and resistance to soil diseases.

The Ribbon Row

The ribbon row produces some fruit in the planting year from new transplants, and high yields in the second year from the high density planting. Site selection and bed preparation are the same as for matted row culture. In most cases, however, the ribbon row is planted on a raised bed, with 3 ft. row centers. Plants are set in late May through late June at a 3 to 6 inch plant spacing within a single row (29,000 - 58,000 plants/A). These high initial plant densities result in high second year yields. Usually plants are set by hand because transplanters cannot achieve such high densities. Compared to the matted row, a later planting date is used so runnering will be less prolific.

After planting, the alley between rows is mulched with straw. Flowers are not removed (so that runnering is suppressed) and some fruit can be harvested in July and August. This fruit can be sold at a higher price because it is produced after the normal June crop. First year yields tend to be 2-3,000 lb/A if high quality planting stock was used.

Runners are removed at regular intervals to ensure that plants develop large crowns prior to winter. Plants are fertilized at regular intervals during the growing season, for a total application of about 100 lbs/A actual nitrogen during the establishment year. Liquid calcium nitrate through the drip irrigation system is a common method of delivery. In cold climates, the planting is heavily mulched in late November or early December. Generally, more mulch is required in raised bed plantings than flat bed plantings. Following mulch removal in spring, the plants flower and fruit. Fruiting occurs at the same time as a matted row planting, but yields per acre are significantly higher than with matted rows, usually exceeding 20,000 lb/A.

Following harvest, the planting is renovated in the same way as matted rows. Since raised beds require additional straw for winter protection, more may be present in the alleyways than can be worked into the soil. Some growers will remove this mulch prior to renovation. Leaves are mowed off, beds are reshaped, and mulch is reapplied between rows.

Since it is impractical to remove all of the runners in the second year, the ribbon rows are allowed to convert into narrow matted rows for the third year. From this point forward, the field is treated as a matted row planting.

Modifications of the ribbon row are increasing in popularity because weed management is easier when initial plant densities are higher.

Pests

One of the most important diseases for perennial growers is Botrytis gray mold (*Botrytis cinerea*). It occurs on fruit whenever flower petals or developing fruit remain moist for an extended period. Spring rains are common where perennial

strawberries are grown. Narrow rows, proper fertility, and fungicides applied at bloom are used to manage this disease. Proper handling and storage of fruit will reduce the risk of infection after harvest.

Twospotted spider mites (Tetranychus urticae) are a major strawberry pest, occurring mainly in warmer production regions. They do not affect strawberry fruits directly, but can reduce photosynthesis in the leaves and lower productivity. Predatory mites are frequently released to keep mites at a level where damage is minimal. The use of certain pesticides and excessive fertilizers will exacerbate mite problems.

Red stele (Phytophthora fragariae) is a significant soil-borne disease on heavier soils in regions where perennial matted row culture is used. Virulent races are apparently spread on infected planting stock, and once infested, a soil may not longer be able to support a susceptible variety. Annual fumigation reduces this disease, but this is not an option for perennial systems. Resistant cultivars, planting on raised beds, improving soil drainage and certain fungicides are used to manage Phytophthora. Different races of red stele occur throughout the world, so resistance may not hold in all locations.

Verticillium wilt can infect susceptible strawberry varieties if they are planted within three years of another infected crop, such as potatoes or tomatoes. Verticillium wilt causes the outer leaves to wilt and die. The disease is most prevalent in first year plantings.

Plant bugs (Lygus) occur throughout the world. Adults and nymphs feed on flower receptacles, damaging the achenes and resulting in deformed fruit. Managing this pest is difficult because insecticides should not be used during bloom when the insect is most active. Properly managing the surrounding habitat can reduce plant bug populations.

Perennial strawberry growers may experience symptoms of "black root rot." Roots blacken in spring and growth is poor. Nematodes, *Rhizoctonia* and *Pythium* have been associated with this disease complex. This condition is most prevalent in sites where strawberries have been planted previously, soils are compacted, or where plant roots are stressed. For example, continuous use of terbacil herbicide has been associated with black root rot symptoms.

Many other pests affect strawberries; most can potentially cause serious economic loss for growers because fruit is so high in value: these include aphids, cyclamen mites, bud weevils, leafhoppers, root weevils, grubs, sap beetles, crown borer, slugs, leather rot (*Phytophthora cactorum*), angular leaf spot (*Xanthomonas fragariae*), powdery mildew, leaf spot, several postharvest pathogens, and a number of viruses and nematodes. There are several good references for strawberry pests, including the Compendium of Strawberry Diseases edited by J.L. Maas and published in 1998 by the American Phytopathological Society, St. Paul, MN and the Strawberry Production Guide

edited by M. Pritts and D. Handley and published in 1998 by the Natural Resource, Agriculture and Engineering Service, NRAES-88, Riley Robb Hall, Cornell University. A web site maintained at Cornell University can assist the grower in identifying the cause of strawberry plant symptoms. Go to <http://www.hort.cornell.edu> and look under Extension/Commercial Fruits and Vegetables/Pest Management for the Berry Diagnostic Tool.

Economics

A. DeMarree and R. Rieckenberg conducted a very detailed budget analysis of matted row strawberry production. Their spreadsheet appears in the Strawberry Production Guide by Pritts and Handley cited above. The example in Table 1 is typical of strawberry growers. In this example, 50% of the crop is harvested for wholesale and 50% is sold Pick-Your-Own. The price per quart (\$1.80 wholesale and \$1.00 PYO) is conservative, but demonstrates that a positive Net Present Value accrues, especially in the first two fruiting years. Their analysis indicated that establishment costs are approximately \$3,400 per acre, positive cash flow occurs after the first bearing year, retailing has more profit potential than PYO or wholesaling, and break-even prices are approx. \$1.00/qt.

Under an organic production scenario, yields were 30% lower and price was 40% higher. Additional time was required for hand-weeding. The breakeven price was \$1.47 vs. \$1.00, but with the higher prices, a profit was realized for the first two fruiting years. After that, yields declined below those which could maintain profitability. Most organic growers fruit their fields for only two years because of fertility concerns and weed pressure.

Their ribbon row economic budget analysis assumed a 2,000 qt. yield in the planting year, and a 30% increase in yield the first fruiting year over the matted row. All other assumptions were the same. With the ribbon row, accumulated net present value was \$3,000 greater than with the matted row after five years.

M. Pritts examined ribbon row profitability, and found that the amount of first year is critical to the success of this system (Assessing the economic implications of research on production practices for strawberry crops. In: A. Dale and J. Luby, eds. *The Strawberry into the 21st Century*, Timber Press, Portland, Oregon). Unless planting year yields are about 3,500 qts, then accumulated net present value is less than with a matted row after three years. Here he assumed that third year ribbon row yields were 25% lower than third year matted row yields (several university studies suggest that this occurs).

With current yields and prices, strawberries continue to be a profitable crop to grow. Strawberry growers in retail and PYO markets have great control over price, so usually can set the price sufficiently high to make a profit. Wholesalers have less control over price, experience a smaller profit per unit, so must produce a larger number of units to justify an investment in strawberries.

