



Production Guide for Texas-Grown Strawberries

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Strawberries are popular in Texas and throughout the United States. One cup of strawberries contains only 55 calories, hence their popularity with health-conscious consumers. Since 1970, yearly production of fresh strawberries in the US has increased 700 percent to 7.4 pounds per capita. This reflects the increasing popularity of strawberries, and suggests there is a viable market for Texas-grown berries.

When managed efficiently, strawberry production offers growers the potential for high profits. However, experience shows that strawberries can be difficult to grow, especially in the semi-arid regions of West Texas, the High Plains/Panhandle and Lower Rio Grande Valley. There is significant interest for growing strawberries in Texas and this guide serves as an introduction to strawberry biology, production techniques, variety selection, marketing strategies, high tunnels, pest management, irrigation, soil salinity and pH, fertility, harvesting and storage. This guide is specific to Texas and is intended only as a reference for potential growers.

Strawberry acreage in Texas has been limited over the past several decades, so little information has been provided by Texas A&M AgriLife Extension and Research. Growers should gather as much information as possible before making significant investments to expand into strawberry production. The collaborating authors have varying years of strawberry production experience, and are experts in selected areas of crop production. Much of the information herein comes from experience obtained from the 2013–2014 NSSI Grant.

Are Strawberries the Right Crop for Me?

Russ Wallace & Joe Masabni

Fresh strawberries are popular with US consumers—consumption increased from 1.7 pounds in 1970 to 7.8 pounds per capita in 2013. They are popular on small farms for fresh market or U-pick sales (Fig. 1). They can be especially profitable when grown near urban centers. However, production costs can be very high and investing in land and equipment for strawberry production requires careful consideration. Current production in Texas is less than 150 acres, while California and Florida have 38,000 and 8,800 under cultivation, respectively.

Before investing time and money, growers should contact Texas A&M Agri-Life Extension Horticulture and Risk Management Specialists, or County Extension Agents to determine the feasibility and market potential in their region.

Questions may include the following:

- ♦ Will I sell my berries wholesale, retail, or U-pick?
- ♦ What marketing strategies are best for my location?
- ♦ Is there a viable consumer base to purchase my berries?
- ♦ Do I have access to an adequate labor force throughout the season?
- ♦ Should I grow organically or conventionally to meet my clientele's needs?

Choosing appropriate production methods is also critical. Options include:

- ♦ Open field
- ♦ High tunnels
- ♦ Greenhouse
- ♦ Hydroponics
- ♦ Annual production
- ♦ Perennial production

Equipment for different production systems can be very expensive and should be researched thoroughly. Row spacing, plastic mulch, and pest control spray equipment may require additional specialized equipment. Wildlife can also be a serious problem in strawberries—they feed on the leaves, flowers, and fruits. Growers must plan for wildlife control for before planting.

Climate is crucial for successful strawberry production. High winds, saline soils, high soil pH, and hot springtime temperatures may limit strawberry production. Strawberry production requires an ample supply of high-quality water.

Strawberries have high water and fertilizer requirements and are especially labor intensive to transplant and harvest. At peak production, strawberries may need to be harvested daily. The number of laborers you will need depends on the size of the field and time of season.

If you plan to grow strawberries, do so only after very careful analysis with horticulture, risk management and marketing specialists, as well as retailers and other producers.



Figure 1: Locally grown strawberries are a very popular crop; however, they can be difficult to find in many areas of Texas.

Strawberry Production in Texas

Russ Wallace and Larry Stein

Strawberry production in Texas has fluctuated over the decades. From 1900 to 1930 most were grown in Galveston, Smith, Brazoria, Harris, and Atascosa counties. The strawberries grew in small family gardens to larger farms with the help of migrant workers. Industrialization after World War II caused production to fall. However, in 1948, strawberries were the most important berry crop produced in the state and total production was 63,000 crates (1,512,000 quarts).

The average annual acreage in Texas from 1937 to 1946 was 1,360 acres. Smith and Wood counties in East Texas along with the coastal area below Houston and the Wintergarden region had the highest production. By 1958, Texas had just 600 acres under cultivation and represented less than one percent of the nation's strawberry production.



Figure 2: Typical strawberry field production in South-central Texas includes bare-rooted plants and furrow irrigation.

In 1960 the USDA reported that the annual Texas strawberry production increased 13.7 percent and by the mid-1960s, production climbed to 2,600,000 pounds. At that time, Texas was one of three states growing early-spring strawberries—commercial strawberries were shipped from Hidalgo, Atascosa, and Wood counties.

By the 1990s, strawberry production for wholesale and fresh market retail sales had blossomed south of San Antonio in the Poteet area (Fig. 2). By 2004, increased importation left Texas annual acreage at less than 150 acres which

accounted for less than 0.02 percent of national production. Today, most Texas strawberry producers grow on less than 5 acres.

Considerations Before Planting

Marketing Strategies

Marco Palma

Strawberry growers in Texas have alternatives for selling fresh berries and choosing the most appropriate market is important to the success of a strawberry enterprise. Production volume, grower location, time available for marketing, and berry quality are just a few factors to consider when choosing a market or markets. Understanding the advantages and challenges of alternative approaches to selling will help producers as they develop marketing strategies.

Strawberry markets are either direct or non-direct markets. With direct markets, growers interact with consumers one-on-one. Direct markets include, pick-your-own (PYO) operations, roadside stands, community supported agriculture (CSA), and farmers' markets. In non-direct markets, growers interact with intermediaries including terminal market firms, shipping point firms, processors, grower cooperatives, brokers, and retail outlets.

Non-direct marketing

Strawberries may be marketed non-directly through terminal market firms, wholesalers, brokers, processors, cooperatives, private packing facilities or buyers for retail outlets. Choosing non-direct markets involves being able to meet the buyer's needs. Buyers may want certain grades and varieties of strawberries and require specific packaging. Buyers may also demand specific volumes at specific times. Small acreage producers must be realistic about their ability to meet large buyers' demands.

Direct marketing

Pick-your-own operations, roadside stands, and farmers' markets, are all direct marketing approaches that benefit both growers and consumers. If producers expect to capture prices from direct markets similar to those that consumers pay at non-direct markets, they must provide the same value of services.

The price that consumers pay at a retail store generally covers the cost of producing, grading, packing, transporting, wholesaling and marketing. To achieve higher net returns, producers should provide services that are not available through non-direct markets, and eliminate unnecessary services. Direct markets benefit the consumers with fresh, high-quality berries directly from growers at competitive prices.

In addition to being a place to buy and sell strawberries, direct-markets also provide a social setting. Growers have the opportunity to meet with friends and neighbors, discuss production practices, display ideas, and use additional fruits and vegetables to attract customers. Consumers have the opportunity to visit local farmers and talk with people who share similar interests.

Although direct marketing has the potential for higher net returns, growers should consider the additional time and effort, production knowledge, and retail selling inherent to direct markets. Direct markets require longer work hours and dealing with the public.

Much direct-market time is spent with customers and is a great time to promote positive attitudes and goodwill. However, time required to operate a direct market can take a grower away from production activities. Many times, family members must handle the retailing of direct-marketing operations, so the grower can manage production.

Pick-your-own operations

With pick-your-own (PYO) operations, consumers come directly to the farm and harvest strawberries themselves (Fig. 3). These operations are feasible for crops like strawberries where it is easy to identify mature product. Varieties that mature at different times can be grown in separate fields to keep them from being picked too early. Consumers often prefer PYO operations because they like to select fresher, higher quality produce at lower prices. Many enjoy picking berries as a recreational activity or family outing.



Figure 3: A pick-your-own operation.

Roadside stands

Roadside stands are a direct market where growers establish a selling location near a roadway and sell strawberries directly to consumers. These are usually on or near the farm or orchard. Strawberries sold in a roadside stand may be grown on the farm or purchased from outside sources. Roadside stands may be open during the harvest season or throughout the year if the stand sells other types of fruits and vegetables. Facilities can be permanent structures or mobile units such as trucks or trailers. A permanent roadside facility that operates year around is referred to as a roadside market.

Farmers' markets

Farmers' markets are an increasingly popular form of direct marketing. These are locations where growers come together to sell strawberries and other produce directly to consumers. Farmers' markets differ from other direct-marketing operations in that growers share the costs of insurance, advertising, and other marketing. Successful farmers' markets help increase the incomes of small farmers who participate in them.

Production Regions in Texas

Russ Wallace and Mengmeng Gu

Thirty-five percent of the land area in Texas has mean low temperatures above the critical level for strawberries. The other 65 percent of land has lows from 0°F to 10°F, which could kill unprotected strawberries. The diverse growing regions in Texas make large-scale strawberry production more complex. Regions range from hot, windy and semi-arid in the Trans-Pecos, High Plains and Panhandle areas, to humid and subtropical in East and Central Texas, and the Wintergarden area and Lower Rio Grande Valley. On the High Plains, strawberries and other high value crops are susceptible to high winds, blowing dust, hailstorms and heavy rains. In the southern and eastern regions, heavy rains and rapid rises in daytime temperatures and humidity at critical harvest times may hurt berry development and promote diseases.

Soil quality is critical to strawberry production; they prefer sandy or sandy loam soils. In the High Plains and other western regions, soil pH may range from 7.0 to 8.3, which is typically high for neutral to acid-loving strawberries. Arid soils and irrigation water can also have high salinity levels and many regions have alkaline clay soils, which can limit strawberry production.

Soils become more alkaline and saline further west and south of San Antonio and Austin, past Midland to El Paso, and even north to the Panhandle. Before investing in strawberry production in those areas, consider the soil and environmental conditions carefully.

Site selection

Joe Masabni and Russ Wallace

Strawberries are expensive to grow and should be planted in locations suited for maximum production. Do not grow strawberries in poorly drained soils (heavy clays, etc.), or low areas that are flood prone. Slightly elevated sites with some slope are preferred.

Strawberries prefer sunny locations with quality soil and grow best where winter temperatures rarely dip below 0°F. Sandy or sandy loam soils are best suited for strawberry production, although high sandy soils that drain excessively may require additional irrigation. Poor soil drainage can increase potential root and berry diseases. Strawberries prefer uniform soil moisture that is not too wet or too dry. Wet and dry cycles can lead to poor quality, misshapen berries.

Soil drainage can be improved by planting strawberries on 6- to 12-inch raised beds and by using plastic mulch. Raising the strawberry bed will remove excess moisture and help prevent over-irrigation. In contrast, adding compost before shaping beds in sandier soils may improve water-holding capacity. Sites with fewer rocks, dirt clods, and trash from previous crops make it easier to lay plastic mulch properly and give a firmer, smoother bed.

Strawberries prefer soils with a pH range of 5.5 to 7.0. Soil should be tested before planting and evaluated every few years. Soils with higher pH levels (7.5 to 8.3) may still be productive. In those soils, iron deficiency may be problematic and cause leaf yellowing and reduced yields. Soil pH can be temporarily lowered with organic materials like compost, peat moss, pine needles, humic acid, or sulfur. Fertilizers such as urea, ammonium sulfate, or ammonium nitrate can also help lower soil pH. Water additives can also lower pH, but they can burn crop roots if not used carefully. Foliar iron chelates may be sprayed to improve growth, though this has not been tested in Texas.

Experience shows that some strawberry cultivars can be injured by high winds and blowing dust. Excessive wind can damage the leaves and stems as well as developing fruit. Using high tunnels, especially in western regions of the state has been shown to significantly increase strawberry yield and quality. For additional information on high tunnels, refer to Texas A&M AgriLife Extension publications (*High Tunnels for Crop Production in Texas*, HT-016; and *Specialty Crops for High Tunnel Production in Texas*, HT-029).

It is important to rotate strawberry fields with other crops to help suppress disease and insect problems. Strawberries can be rotated with cover crops like rye, barley, wheat or other legumes, which increase nitrogen levels in the soil. Research conducted in California shows that neither rye nor barley host pests that attack strawberries. Rotating with vegetable crops may improve future weed control. Provide enough time for crop residues to break down, otherwise the crop stubble can make it difficult to lay plastic mulch evenly.

Row orientation can also improve strawberry production. North-south orientation enhances plant uniformity and berry ripening. Where fields are mostly flat, you can use row orientation to improve soil drainage in case of heavy rainfall.

Equipment and Supplies

Russ Wallace and Joe Masabni

First-time growers must consider the cost of specialized equipment when developing a production plan. Factors include acreage to be cultivated, whether tractors or other needed equipment are already on-farm, and if existing equipment can be used or adapted for strawberry production. Strawberries grow best on raised beds, so growers need equipment to create beds that are at least 6- to 12-inches tall.

Bed shapers can be expensive; therefore, it may be best for new growers to lease equipment or hire a local contractor. Contractors can also fumigate the soil (if needed), and lay the drip tape and plastic mulch efficiently. Raised beds should



Figure 4: Raised beds with drip irrigation and plastic mulch are an important method in annual strawberry production.

be firm and uniform, and plastic mulch should be laid tightly over the bed to keep it from tearing during high winds (Fig. 4). Loose plastic can damage plants, and it takes time and effort to replace it. If investing in new or used equipment, be prepared to spend \$5,000 to \$10,000 or more.

Weed control is critical, especially between the crop rows. Growers can use standard cultivators but may need to adapt them to decrease the risk of tearing or pulling the plastic mulch. The wheel spacing on tractors may also need to be changed to match row spacing. Strawberry beds should be from 1.5- to 4-feet wide.

An overhead sprinkler system will help bare-root or plug establishment during the first week, even when plastic mulch is used. Sprinkler systems

can cool the crop during high heat and keep flowers from aborting; they can also protect the flowers from freezing during cold temperatures. Low impact sprinklers are preferable and new or used overhead systems can cost between \$1,500 and \$3,000 per acre. Before purchasing an irrigation system, you must know the pumping capacity of your water source.

Many Texas producers are using furrow irrigation for bare ground strawberries. However, in plasticulture, drip tape must be placed just below the bed surface. Drip tape with 12-inch emitter spacing works best for strawberries. Expect to pay \$120 to \$180 for a 6,000 to 9,000 foot rolls.

Strawberry growers generally transplant plugs or bare-root plants by hand. Equipment is available that can punch holes through plastic mulch—this equipment can be expensive. With trained labor, an acre of strawberries can be planted in a one to two days.

Other supplies you may need include: deer fencing and bird netting (especially for less than an acre or two), spray equipment, baskets or containers for harvesting, crates or wagons to carry from the field to the vehicle for transporting, and coolers to remove field heat from the berries. You may need additional supplies depending on whether you choose direct or non-direct marketing.

Plant Quality and Sources

Russ Wallace and Joe Masabni

You should always purchase plants from a reliable source. The success of the crop depends on purchasing healthy, vigorous plants. Depending on the varieties you choose, you may need multiple sources. Many plants sold in the US are started in Canada and then sold to plug or bare root propagators around the country. If you buy from local propagators, be sure the plants originate from a reliable source.

Before planting, inspect all plants for foliar or root diseases, viruses, weeds, and insects. Bare-root plants should have good, healthy roots. Be careful not to break any leaves or stems emerging from the crown. Freshly dug bare-root plants that are chilled at the nursery will establish more quickly than those produced in warmer climates.

Plug plants should have healthy, white roots with vigorously growing leaves and stems emerging from the crown. Plants that have been held for extended periods may have runners; it is best to remove those before transplanting.

A good place to find strawberry plants is <http://strawberrypants.org/2010/05/strawberry-plants-for-sale-online/>. This site has a directory of strawberry plant suppliers and has information on varieties and types of plants. Discuss your needs with the supplier before placing your order. Suppliers should know which varieties would work best for your location. You can also contact the Department of Horticultural Sciences at Texas A&M University for additional information. Remember that to transplant strawberries in Texas during the fall, you must place orders by early June or July.

Production Systems

Russ Wallace and Mengmeng Gu

The matted or space-matted row system and the hill system are the most widely used production systems for planting perennial June-bearing strawberries in the US. These are popular in Northeast and do not use plastic mulch. Bare root plants are considerably cheaper and are preferred for these systems. The matted-row system involves planting mother plants and allowing them to spread by runners over the entire bed. In the space-matted row system, the runners are actually spaced by hand to achieve a more uniform system. Strawberries in those systems can be planted on hills and are generally spaced at 12 to 15 inches in the row and 36 to 48 inches between rows.

Ever-bearing and day-neutral varieties grow best on the hill system. Like with the matted rows, it is cheaper to transplant bare root plants. Transplant bare root plants with 12- to 15-inch in-row spacing in double or triple rows per bed. Between-row spacing should be 1.5–2.0 feet to allow for workers or consumers to harvest the berries.

Plasticulture uses colored (black, white, red, etc.) polyethylene mulches that are generally 48 to 60 inches wide. In plasticulture, drip tape is placed just beneath the soil surface on beds that are typically 2.5 to 3 feet wide or wider. Strawberries are transplanted 12 to 15 inches apart in 2 to 4 rows. Wider mulches can be used for four-row beds; however, in those systems two drip lines should be used. Holes are punched into the plastic and strawberry plugs planted in them.

Other popular systems include growing strawberries in greenhouses using hydroponic gutters or hydrostackers, or in the soil inside high tunnels. High tunnel strawberry production is similar to open field plasticulture, but the crop is protected with a plastic covered frame. Texas A&M AgriLife Extension Specialists have shown high tunnel production to be successful in Texas (Fig. 5).



Figure 5: High tunnels are a popular technology for growing strawberries. They can improve yield and quality and extend the growing season.

Growing Strawberries Organically

Justin Duncan

Consumers demand for organic strawberries has steadily increased. To produce organically, growers need to address fertility, pest and disease control without synthetic chemicals. Organic production of strawberries relies on nature; it is not simply replacing synthetic chemicals with organic ones.

Soil fertility

A strong organic field starts with soil fertility. The infection triangle (environment, host, pathogen) stresses that there must be a susceptible host for disease to develop. In this model, insect pests can be considered symptoms of unhealthy plants. To keep plants healthy, producers must manage soil fertility by adding needed mineral sources that are rich in trace elements and micronutrients. Strawberries are relatively heavy feeders so it is essential to boost soil fertility before planting and then supplement as the season progresses.

Rotation

Rotating strawberries with legumes allows nitrogen to build up in the soil naturally. Giving the soil a break from the heavy feeding strawberries also allows the soil to recharge minerals from the amendments. Fall plantings benefit from a cowpea cover crop the preceding summer; spring plantings benefit from crops like Austrian winter peas. Though it is easier to incorporate winter peas into the soil, the strawberry plants can benefit from the longer lead-time of fall planting.

Insect pests

Insect pests can be one of the most frustrating parts of strawberry cultivation. Fortunately, nature provides natural enemies for strawberry insect pests. Farm-scaping is the cultivation of crops specifically designed to attract and maintain beneficial insects. These crops attract beneficials by serving an alternative food source and breeding ground. This technique is useful for reducing pest populations in organic growing systems. Organic products can be used to help knock down pest populations but, as mentioned before, these are symptoms of a system that may be out of balance. Healthy plants can prevent pest build up and disrupt their life cycles.

Weed control

Weed control can be a major problem for organic strawberry producers. Many winter weed species grow at the same time as strawberries, but products used to control weeds can harm strawberries.

Organic culture is a long-term proposition; natural solutions for weed control should be implemented seasons ahead of planting dates. Continual rotation with smothering cover crops can greatly reduce weed populations. It is essential to know the soil and seasons so weeds can be disrupted and reduced cyclically.

Before planting strawberries in open ground, several shallow tillings a few weeks apart should effectively pregerminate weed seeds and reduce weed problems for the season. Many producers have opted to use plastic mulch for their strawberry plantings.

Growth and Development of the Strawberry Plant

Strawberry Biology

Monte Nesbitt and Larry Stein

The strawberry (*Fragaria x ananassa*), is a small evergreen plant of the rose family (Fig. 6). It is a low-growing plant with tri-lobed leaves and shallow-growing fibrous roots. Roots and leaves arise from a thick, semi-woody structure called a crown. The crown is a perennial structure and there are usually multiple crowns for each plant. With each season of growth new leaves and roots emerge from higher and higher positions on the crown. This plant seemingly grows up out of the ground. The crowns initiate stolons or runners that extend from the original crown to form new daughter plants. The strawberry plant likely got its name from the appearance of the many thick runners, which resemble straw. If allowed to grow close together for enough time, the runners will proliferate and form dense fruit-bearing mats.

Cultivated strawberries were initially bred in France in the 1750's. This breeding crossed a North American native species (*Fragaria virginiana*) and a South American species from Chile (*Fragaria chiloensis*). The popularity and spread of garden strawberries is a result of its flavor and texture and by historical belief that they have medicinal properties.

Strawberry plants develop predictably in phases. Dormant crowns will form new roots and leaves; then flower and bear fruit. Plants will then stop flowering and form runners and daughter plants in that sequence. Soil and air temperatures affect the timing and duration of the different phases. Though strawberries generally grow and develop best at 70 to 75°F, strawberry breeders have produced varieties that grow and bear fruit in somewhat cooler or warmer climates.

Strawberries are fibrous-rooted plants that do not root deep into the soil. Depending on soil conditions and mulch and irrigation practices, most roots penetrate only the top 6 to 12 inches. Strawberry roots need good soil moisture but must also have good aeration. Well-drained soils are essential to root health and plant growth and fruiting. Plants standing in water even for brief periods are likely to become unthrifty or die.

All strawberry flowers have male and female structures and are somewhat self-pollinating (Fig. 7). Pollination occurs naturally with wind and movement of the flowers. However, bees and other insects can increase the pollination rate and improve berry yield and quality. The flower pistils become receptive in successive rings starting at what will form the base of the fruit. The progression of pistil maturity takes 4 to 7 days, during which time several bee visits are required for a well-formed fruit to develop.



Figure 6: A healthy strawberry plant with leaves, blossoms, developing fruit, and mature berries.



Figure 7: The strawberry flower has male and female parts and is generally self-pollinating. Wind and bees can improve pollination.

Although the fruit resembles a conical berry, the fruit is more correctly identified as an accessory fruit or pseudo fruit, formed from an enlarged flower receptacle embedded with the many tiny ovaries or achenes. Achenes resemble tiny seeds on the outside of the berry. New varieties of strawberries come from controlled pollination and planting selected seeds, whereas genetically identical plants arise from the runners off the mother plant.

Types of strawberry varieties

Strawberry varieties are categorized according to their flowering response to day length. Three general categories are used to describe flowering performance: short day (also called 'June bearing' or 'spring bearing'); long day (also called 'everbearing'); and day neutral.

Spring-bearing (short-day) varieties

The most successful commercial varieties in Texas are the short-day varieties. These short-day varieties are commonly called 'June-bearing' in much of the United States, because June is usually the time for peak production. In Texas and other southern states, short-day strawberries are planted in the fall. They are protected with covers during the winter and early spring and are harvested in the spring, thus the term 'spring bearing'. The flower buds start during the autumn months when day length is 10 hours or less. Flowering is suppressed by cold mid-winter temperatures, and begins when temperatures get warmer. Depending on production system, short-day strawberries in Texas are commonly harvested from late February to May or early June (Fig. 8).

Spring-bearing strawberries produce one crop and typically yield the majority of the fruit during a 10- to 14-day window. They switch to the runner production phase once day length and temperatures increase. Different spring-bearing varieties may have slightly earlier or later flowering and ripening dates. Growers that want to extend the harvest season should consider planting a mix of varieties for early, midseason or late harvests. Spring-bearing varieties produce many runners and daughter plants, making them suited to a matted-row or annual hill systems.

Examples of spring-bearing varieties recommended in Texas include: 'Chandler', 'Douglas', 'Camarosa', 'Sequoia', 'Festival', 'Oso Grande', 'Radiance', 'Camino Real', and 'Benicia'.

Everbearing (long-day) varieties

Long-day or everbearing varieties initiate flowers when day length is 12 hours, but struggle to flower consistently at temperatures above 90°F. These conditions are common in Texas during the summer months so everbearing varieties are generally not suited for open-field production. They are



Figure 8: Short-day variety 'Festival' laden with berries in early April in Lubbock.

only suitable for commercial production in Texas if grown in climate-controlled greenhouses. In temperature-controlled environments, day-neutral varieties would be a better choice as they bear more steadily in optimal conditions. Ever-bearing varieties also produce fewer runners than spring-bearing types.

Day-neutral varieties

Day-neutral varieties are insensitive to day length. They are an improvement over everbearing varieties because they can flower and bear fruit over a range of light periods. Like everbearing varieties, day neutrals are affected by air temperature. They will flower and form runners at 35 to 80°F, though flower bud formation declines above 70°F. Temperatures of 90°F and above damage fruit production and runner formation. With few exceptions, these varieties generally produce fewer runners than spring-bearing types.

In Texas, day neutrals are used in similar production systems as short-day strawberries, because they are limited by temperatures. In many areas of Texas, outside temperatures may exceed the threshold for forming fruit buds in day-neutral varieties as early as April.

Day-neutral varieties recommended in Texas include:

‘Seascape’, ‘Albion’, and ‘San Andreas’.

Selected Varieties for Texas

Larry Stein and Russ Wallace

Finding quality plants is a challenge and you must order early. To begin transplanting in the fall, you must choose the varieties you want and order by June or July. The following are leading commercial varieties—those recently evaluated by Texas A&M AgriLife Extension are underlined. Growers should evaluate varieties on a small scale before committing to large-scale production. To be profitable, varieties should produce over 1.25 lbs per plant.

‘Albion’ is a day-neutral variety with large, firm, conical, dark-red berries that are good for storage and shipping. It has shown excellent resistance to root diseases.

‘Benicia’ is a spring-bearing (short-day) variety with mild flavor and excellent shape. It has good early potential for yield.

‘Camino Real’ is a spring-bearing (short-day) variety similar to ‘Camarosa’ but later in production and berries are externally and internally darker.

‘Chandler’ is a leading June-bearing variety that produces a vigorous, productive plant with large to medium-sized fruit. The berries are conical to wedge shaped with medium, red, glossy finish. The fruit quality is excellent, and produces high yields. Berries are less firm than ‘Albion’.

‘Camarosa’ is an increasingly popular variety with commercial growers in Texas. It is widely adapted to many growing regions. It has larger and firmer fruit than ‘Chandler’. Berries are very flat and conical.

‘Douglas’ was the leading commercial variety in Texas prior to ‘Chandler’. It is a versatile plant that produces good crops of quality fruit, which are a bit smaller than ‘Chandler’ and typically has nice amber-yellow achenes.

‘Festival’ has produced commercially acceptable yields of firm, attractive, and flavorful fruit in Texas trials. It is recommended for areas where strawberries are grown in the annual hill plasticulture system.

‘**Oso Grande**’ produces a very large, firm berry with high yields. Fruit color and flavor tend to be variable, but fruit are usually conic to wedge shaped with a distinctively rounded tip.

‘**Radiance**’ is an increasingly popular June-bearing variety. It produces large conical berries early in the fall and even during the winter months. However, plants may be susceptible to damage in high wind regions, and can be susceptible to crown rots.

‘**San Andreas**’ is a day-neutral variety that is similar to ‘Albion’. The berries have a glossy skin finish, firm flesh and have good rain resistance. It produces fewer runners than most everbearers.

‘**Seascape**’ produces a more vigorous plant with darker foliage than ‘Chandler’; production is a bit less, but it has larger fruit. The vigorous plants are virus resistant and thrive in a wide range of growing conditions. The bright red fruit are firm, conical, and have an attractive glossy finish with excellent flavor.

‘**Sequoia**’ is a very adaptable variety that has been around a long time. Production is similar to the varieties above though fruit is smaller. This variety produces a deep red color signaling that it is ripe. An ideal home garden variety, the berry turns from firm to soft when it is ready to be picked.

Plugs Versus Bare-Root Plants

Monte Nesbitt, Mengmeng Gu and Larry Stein

In Texas, the annual hill plasticulture system for growing strawberries is best when started in the fall with new, healthy plants. Commercial strawberry nurseries produce replacement plants each year as either bare-root daughter plants or as plantlets grown as plugs in soilless media.

Bare-root plants require more time in the nursery for daughter plants to form good roots. Fresh bare-root plants in Texas generally are available during September to be packed in boxes and shipped to the grower location. Roots must be kept moist during handling and preplanting. If not transplanted soon after arrival, they should be refrigerated and the roots inspected frequently to ensure they do not dry out.

Planting quickly after receipt usually translates into higher survivability and a better plant stand. Because bare-root stock is not available until later and must be planted quickly, growers should prepare fields, beds and irrigation in advance. Some bare-root plants are frozen when dug in August or September; these plants are held in cold storage until the following growing season. Such plants show exceptional growth when handled properly.

Plug plants are generally more expensive than bare-root plants as they are propagated by placing runner tips into plug trays of soilless growing media. Once the tips have rooted in the media and have started to grow leaves, the plugs can be shipped to the grower. Plugs are generally available sooner than freshly dug bare-root plants. They can be smaller and have less root development, so they require good watering and care before, during and after planting. Plug plants grow rapidly and are typically ready before freshly dug bare-root plants.

Transplanting strawberry plants correctly is important for plant success. Plugs are suitable for mechanical transplanting with a water wheel or mulch planter; you must plant bare-root plants by hand. Bare-root plants may have to have their roots pruned. Do not bury the growing tip, but avoid the wicking effect by planting deeply enough so that no root structure is exposed.

Irrigation, drip, or overhead sprinklers should be in place before transplanting to ensure access to water right after planting. Water the plants immediately. Overhead water may be desirable as it increases air relative humidity and reduces water loss from transpiration.

Pollination

Russ Wallace

Strawberry flowers are self-pollinating; they produce both pollen and nectar. Each flower must be pollinated evenly to produce a full berry and cross-pollination produces more fruit than self-pollination.

Self-pollination by wind is enough to produce good yields, but pollination from wild bees or purchased bumblebees can increase yields 20 to 30 percent. It also improves market value and berry shelf life. Unpollinated or poorly pollinated flowers lead to misshapen berries. Full pollination can require as many as 10 to 20 pollinator visits to a flower. Depending on bee activity and weather, this can take 3 to 7 days.

Bee-pollinated fruit may be heavier and have fewer malformations. In addition, bee-pollinated fruit may be redder, firmer, and have a lower sugar acid ratio. Bumblebees are more efficient pollinators than honeybees because they visit more flowers daily (Fig. 9).

Bees are generally most active during the morning and early afternoons and when temperatures are between 50 and 85°F. Avoid overheating hives inside high tunnels by raising the side ventilation systems when it is hot. Honeybees use sunlight for navigation so they do not work as efficiently inside high tunnels or greenhouses.

Bee activity also depends on flowering patterns. When the crop does not have enough flowers, bees will go elsewhere. This reduces their efficiency when strawberries are in full bloom. Mow nearby weeds regularly to keep them from flowering and competing with the strawberry crop. Use insecticides cautiously and do not spray them directly onto the crop during peak bee activity.

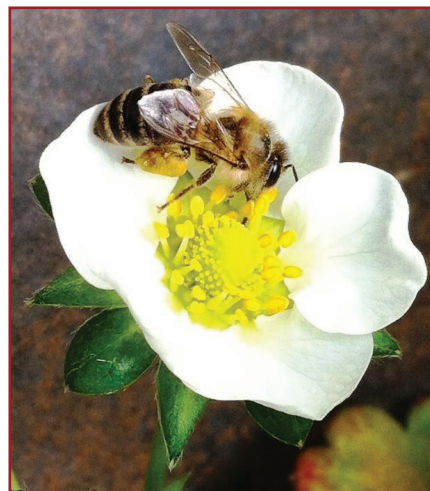


Figure 9: Honeybees will help improve pollination and overall quality of the berries.

Nutrition and Fertilization

Nutrient Needs

Monte Nesbitt and Larry Stein

To produce strawberries successfully you must meet the plant's nutrient needs throughout the growth and production phases. As with any crop, deficiencies of essential elements can reduce growth, production, and fruit size. It is equally important to avoid nutrient toxicities or imbalances by over fertilizing. Applying fertilizers needlessly can also harm the environment.

Soil testing is a key tool for developing an efficient and effective strawberry nutritional program. Collect soil samples for routine nutrient analysis before preparing beds so that any recommended fertilizers can be easily incorporated into the soil. Have the soil tested four to six months before planting to give phosphorus and potassium time to become available to the developing plants. Information

on how to collect a soil sample properly can be found at <http://soiltesting.tamu.edu/publications/E-534.pdf>. Collect samples according to the shallow rooting of the strawberry plant, as well as planting bed construction and the depth of previous fertilizers.

Strawberry plants grow best in soils with a pH of 5.5 to 7.0. Soil reports generally recommend adding limestone to raise the pH values below 6.0. Limestone reacts and moves very slowly in soil. Strawberries prefer slightly acidic soil, so it is important to avoid raising pH too high with limestone. Neutral to alkaline pH (equal to or greater than 7.0) soils are more prevalent in Texas than acidic soils, so it is more likely that strawberry growers will need to lower soil pH than raise it. You can lower soil pH over a period of years by using acidic fertilizers, specifically ammonium sulfate. You can also use liquid-feed fertilizers to reduce pH. Amending soils with compost, composted manure or acidic organic mulches, such as pine needles can also slightly reduce soil pH.

Alkaline soils (pH 7.1 to 8.5) may indicate that the soil contains free calcium carbonate. Such soils require the addition of elemental sulfur or sulfuric acid to lower the pH. It can take large quantities of these materials depending on the level of calcium carbonate in the soil. They also can take 2 to 10 years to completely change the pH of soil. It is typically very hard to lower the pH in such soils, so strawberries may experience iron deficiency. Applying iron chelates to the soil or plant's leaves can help to prevent chlorotic (yellow) leaves (Fig. 10).



Figure 10: High pH soils may influence nutrient uptake resulting in a deficiency or toxicity. These leaves suggest iron deficiency.

Soil tests also tell the grower if the soil needs additional nutrients such as potassium (K), phosphorus (P), magnesium (Mg), calcium (Ca) and sulfur (S). Phosphorus, Ca, and Mg deficiencies in Texas are rare; however, it is not uncommon for soils to be low in K and require fertilizer before planting. Soil testing can also identify high levels of sodium (Na) and excess total salinity.

Nitrogen (N) is the most essential nutrient for root, leaf and runner growth, and fruit production. Since nitrate nitrogen is leached from soils over time, it must be applied for each crop. It is a good practice to incorporate N into the soil before transplanting. Rates of 45 to 60 pounds of actual N per acre are common. This initial rate will promote vigorous plant development. Supplemental N is generally provided as a granular side dress in matted row or annual field culture where no plastic mulch is used. In plasticulture systems, supplemental N is most effectively delivered through the drip irrigation system. Begin supplying N fertilizer when plants start to blossom. Slightly higher rates of P may also improve flower production. Total supplemental N per acre during the flower and fruit production period should be equal to that applied before planting.

The need for supplemental N or other nutrients and rates to apply on strawberries can be refined

by collecting tissue samples and submitting them to a plant testing laboratory for elemental analysis (<http://soiltesting.tamu.edu/publications/E-534.pdf>). Leaf analyses help growers by showing the effectiveness of their fertilizer program. Leaf and petiole tissue are used in commercial strawberry production to assess N, P, and K as well as other nutrients. Texas currently has no established strawberry sufficiency levels for either tissue.

Table 1 shows leaf sufficiency levels for nutrients reported for Ohio and Florida that Texas growers may use as a reference. The values shown are for whole leaves (blade plus petioles) collected from mature, healthy plants during the harvest period. Where nutrients are sufficient or high, growers should apply the same level of fertilization on next year's crop. Where nutrients are below sufficiency, the next year's fertilizer for those particular nutrients should be increased.

Table 1. Plant Nutrient Sufficiency Ranges (whole leaf; dry weight basis).

Macronutrients	Ohio (Ellis, et al., 2006)	Florida (Hochmuth and Albrechts, 1994 & 2003)
	Sufficiency Range (%)	Sufficiency Range (%)
N	3–4	2.8–3.0
P	0.2–0.4	0.2–0.4
K	1.1–2.5	1.1–2.5
Ca	0.5–1.5	0.4–1.5
Mg	0.25–0.45	0.2–0.4
S	0.15–0.40	0.2–0.8
Micronutrients	(ppm)	(ppm)
Fe	50–300	50–100
Mn	30–300	25–100
Zn	15–60	20–40
Cu	3–15	5–10
B	25–50	20–40

Salinity and pH

Genhua Niu and Mengmeng Gu

Salinity is measured as the concentration of dissolved mineral salts in water or soil. Constituents (ions) of salt usually found in water and saline soils include sodium (Na), magnesium (Mg), chloride (Cl), calcium (Ca), sulfate (SO_4^{2-}), bicarbonate (HCO_3^-), and others. The proportions and amounts vary widely by location. High salinity soils can stunt plant growth and cause leaf burn or even death. If salt stress persists or increases, the symptomatic area can expand and the plant eventually dies (Fig. 11).

Salts often accumulate in soils that are highly fertilized and/or irrigated with water that has high mineral concentrations. These soils are more prevalent in arid and semiarid regions where rainfall is low and evapotranspiration high. It is highly recommended that growers test soils for salinity before growing strawberries.



Figure 11: Increasing salinity levels (from left to right) show increasing symptoms of leaf yellowing and marginal burning.

Overall salinity is the concentration of total dissolved solids (TDS) in water. In farming, overall salinity is commonly estimated by the electrical conductivity (EC) of the irrigation water or a soil sample and is directly related to the concentration of salts.

Strawberries are one of the most salt-sensitive crops. However, varieties differ in their tolerance. Selecting salt-tolerant strawberry varieties is an effective approach to preventing yield and quality reductions.

The research on strawberry salt tolerance in Texas is ongoing; however, other studies show that strawberries respond differently to low, medium and high salt levels. A two-year field study showed yield reductions up to 27 percent and 64 percent in 'Korona' and 'Elsanta' strawberries, respectively. Fruit quality evaluated by a consumer panel, showed that taste, aroma, and texture decreased by more than 24 percent with 'Elsanta', but did not change with 'Korona'. Shoot growth reduction varied between varieties; with a reduction up to 90 percent in 'Elsanta' while only 40 percent in 'Korona'.

Other research indicates that strawberries grown under increasing concentrations of sodium chloride (NaCl) had decreasing shoot weights and leaf area as the EC of the irrigation solution increased. Growth reduction was less in 'Elsanta' than in 'Elsinore' indicating higher salt tolerance for 'Elsanta' than 'Elsinore'. Other studies also confirm the varied responses of strawberry varieties and indicate the importance of variety selection in areas with saline soils or high salinity irrigation water.

Strawberry plants are especially sensitive to high chloride levels. Chloride toxicity symptoms include premature leaf yellowing followed by progressive death from the leaf margin inward. Sodium sulfate and sodium bicarbonate do not cause immediate harmful effects in strawberries, whereas sodium chloride and potassium chloride cause immediate damage. Strawberry plant response to salinity may also depend on the growth stage, soil type, and the growing environment.

Information available on the effects of soil pH on strawberry growth and yield in Texas is limited. However, acid soils with a pH of 4.0 are less suitable for strawberry production than alkaline soils with a pH of 8.0. With these extreme soil pH values, strawberry yield potential and fruit quality is damaged by excessive or reduced nutrient uptakes. Studies on the effects of soil pH on strawberry are underway with Texas A&M AgriLife Research and Extension.

Soil should be analyzed for pH as it affects soil nutrient availability to plants. Soil pH between 6.0 and 6.2 promote the best growth in strawberries and ensures

many essential nutrients are available for plant growth and development. Macronutrient deficiency may occur when soil pH is too low and micronutrient deficiency when it is too high. Lower acidic soil pH can be adjusted with lime and higher alkaline pH with sulfur. Different forms of lime and sulfur affect the speed of pH adjustment. Temperature, moisture and soil buffering capacity affect the speed of pH adjustment. Allow about two months before transplanting strawberries after soil liming or acidification. Soil pH and nutrients should be monitored and adjusted when nutrient deficiency is detected. Soils with excessive amounts of certain elements (Cl^- and Na^+) are more likely to affect plant growth and should be avoided.

Soil Amendments

Mengmeng Gu & Genhua Niu

Strawberry producers need to select sites with ideal soil. Soil rarely is ideal, but amendments can help growers achieve the proper pH range, good drainage and water retention properties, and a long-term source for nutrients.

Lime and sulfur

Lime (increases pH) and sulfur (decreases pH) are used to correct soil pH to an ideal range of 6.0 to 6.2. At the same time, Ca^{2+} (calcium) or SO_4^{2-} (sulfates) become available to plants; both are essential for plant growth. Irrigation water and fertilizer could both potentially affect soil pH, so routine (at least annual) soil testing is recommended.

Sand and bark

If soil has too much clay, drainage could be a problem. Sand or pine bark (less than 1/8 inch) can be added to improve aeration and draining.

Crop residues and cover crops

If strawberry production follows another vegetable crop or cover crops, crop residues and cover may be incorporated into the soil before strawberry transplanting. It takes about 3 to 4 weeks for incorporated crop residue/cover crop to decompose. Crop residues and cover crops improve the soil's physical properties and fertility.

Compost

Composts can be produced from plant-based and manure-based organic materials. These include crop residues, animal manures, cottonseed hulls, peanut hulls, pecan shells, bark, hardwood chips, and shredded paper. Compost is a stable, relatively uniform organic material and is made by decomposing (composting process) the materials mentioned above. Using composts as a soil amendment can increase the soil's organic matter content and fertility, as well as its physical, chemical, and biological properties. Compost can be spread on the surface or incorporated into the soil. The nitrogen content in compost alone is normally not enough to meet strawberry growth and development needs. Soil must be tested to establish how much supplemental nitrogen is needed.

Manure-based composts often contain more phosphorous than plants can take up. Repeated high-rate application of manure-based compost may cause phosphorous accumulation in soil. Excess phosphorous can also become a become nonpoint source of pollution and affect plants' uptake of other nutrients.

Water Management in Strawberry Production

Daniel Leskovar and Alma Solis-Perez

Water management is critical to maximizing strawberry yields. Water stress can affect plant growth during early development because strawberries have a shallow root system (6 to 12 inches). Water stress during fruit development can reduce fruit size, yield, and berry quality. Conversely, overwatering may be even more harmful because it increases the risk of root diseases, slows root growth, increases iron chlorosis (particularly on alkaline soils), and leaches nitrogen, sulfur, and boron out of the root zone. This can lead to nutrient deficiencies and increase water and fertilizer costs.

A uniform and adequate water supply throughout the entire strawberry season is important for successful establishment, plant growth and frost/freeze protection. In commercial strawberry farms, overhead sprinkler irrigation is used for establishing bare-root plants, followed by drip irrigation for subsequent production.

The establishment phase can account for up to one third of the total seasonal water use (14 to 20 inches) in strawberries. In Florida, strawberry growers use high-impact sprinkler irrigation systems (4 to 5 gal/min/head) to irrigate bare rooted plants continuously for about 8 hours daily for the first 10 to 14 days after transplanting. Although they can cost almost twice as much as bare root transplants, using containerized strawberry plug plants reduces irrigation needs during the establishment period, and enhances early growth and flowering.

In annual hill systems, growers typically place one drip line in the middle of 30-inch beds or 2 lines on 45-inch beds approximately 2 to 4 inches below the soil line and under the plastic mulch. A grid of low impact sprinklers are also used throughout the field during establishment. Although installing subsurface drip irrigation systems is costly, they are highly recommended for strawberries. The main advantages of drip irrigation are the precise application of low water volumes, better management of irrigation and fertilization (fertigation), lower pumping needs, automation, adaptability to different fields' shapes and the improved cleanliness of harvested berries. In addition, drip systems combined with plasticulture can reduce weed and disease problems.

In warm climates after establishment, strawberries grown in plasticulture are typically irrigated with 18 inches of water over a 200-day growing season. However, the strawberry plant actually uses only 55 percent of this amount. Significant volumes are lost to leaching, evaporation, inefficient application and an inadequate ability to assess the daily water requirements of the plants.

The goal of a well-managed irrigation program is to maintain soil moisture between field capacity (the amount of water held in a soil after the excess has leached out) and the point of allowable depletion (the point where plants begin to experience drought stress). For strawberries, the amount of allowable depletion is about 50 percent of the total available water in the soil. Therefore, apply water when no more than half of the available water has been depleted.

Soil properties greatly influence soil moisture so you must know your soil's water retention capacity in order manage irrigation effectively. The volume of water that is readily available to strawberries depends on the soil water holding properties and the crop root zone. Maintaining the soil moisture in the readily available range requires close monitoring of the soil water content, tracking water loss to evapotranspiration (ET), and water input from irrigation and rainfall.

Typically, soil moisture content is monitored with tensiometers, electrical resistance blocks, or dielectric soil moisture sensors (Fig. 12). Estimates of ET are based on weather data including air temperature, relative humidity and wind speed. Reference evapotranspiration (ET_o) refers to the expected water use from a uniform green cover crop surface, such as grass. In Texas, this value is obtained from the weather station (<http://texaset.tamu.edu/>) closest to your production field. The actual crop use (ET_c) is generally less than the ET_o. This can be determined by multiplying ET_o by a correction factor or crop coefficient (K_c) that is specific to strawberries at particular stages of development (see equation below).

$$ET_c = ET_o \times K_c$$

For strawberries, the K_c ranges from 0.16 at dormancy break or roughly at transplanting (growth stage percent = 0), and reaches a maximum of 0.95 around full bloom (growth stage percent = 80 to 140), then decreases down to 0.10 at the end of the crop cycle (see Table 2 below).

An alternative for estimating ET_o uses an atmometer (Fig. 13) which is designed to simulate ET from a plant canopy in a way that closely resembles the crop ET. Atmometers have been gaining popularity because they are simple and can provide an on-site ET_o. The ET_o can be estimated by recording the decrease in water level (from the graduated sight tube) over a period of days and then multiplied by the K_c to determine crop water use (see equation above).

Regardless of method, efficient irrigation in strawberries is critical to high-quality yields. Soil moisture levels should be monitored regularly to ensure the strawberry crop receives adequate and timely moisture.



Figure 12: Monitoring soils for appropriate moisture levels will increase water use efficiency and reduce potential root diseases.



Figure 13: Atmometers are popular for measuring soil moisture levels. They offer a simple way to measure on-site evapotranspiration.

Table 2. Crop coefficients for strawberries according to the growth stage

Growth Stage (%)	Crop Coefficient	Growth Stage Indicators
0	0.16	
10	0.17	
20	0.24	
30	0.35	
40	0.48	
50	0.62	Break Dormancy
60	0.76	
70	0.89	
80	0.95	
90	0.95	
100	0.95	Full Bloom
110	0.95	
120	0.95	
130	0.95	
140	0.95	
150	0.89	
160	0.80	Killing Frost
170	0.67	
180	0.51	
190	0.32	
200	0.10	

Pest Management

Integrated Pest Management (IPM) combines cultural, mechanical, preventative, and monitoring techniques to manage pests in the most sustainable and economically viable manner. Although it can be tempting to create a weekly spray schedule, unnecessary sprays can be costly. Weekly preventative sprays can also promote pesticide resistance, harm beneficial insects, and result in higher costs with potentially lower yields. Unnecessary pesticide use can have a negative impact on human health and the environment.

Implementing a strong IPM program requires knowledge about the biology and ecology of the crop, key pests, plant diseases, and the soil. The following are insect pests and plant pathogens that you may encounter while growing strawberries in Texas. This information can help you design an effective IPM strategy.

Insects

Erfan Vafaie and Pat Porter

Aphids

Damage

Aphids damage leaves and whole plant health, and may damage fruit indirectly.

Symptoms and identification

Aphids are sucking insects whose populations can grow rapidly. They can stunt plant growth, vector viruses, and they secrete honeydew, a sticky residue that can encourage fungal pathogen growth on plant leaves and fruit. High aphid populations can cause leaves to curl and dry out, and if left unchecked, kill the plant.

Aphids are green, dark green, black, orange or red. They have six legs, two antennae, and two cornicles (tube-like structures located on their posterior). In high densities or degraded habitats, aphids can form wings and fly to other plant hosts.

Monitoring

Look for aphids on the underside of leaves, near major leaf veins on lower leaves and on new vegetative growth. University of California researchers suggest sampling 40 trifoliolate leaves weekly within each acre and managing aphid populations when infestation rates reach 30 percent or above. Ant populations can be a sign of aphid infestation, as ants will defend and farm aphids for their honeydew. Aphids can infest isolated regions of your crop, and can spread rapidly if left unchecked. Aphids should be monitored throughout the season, even during winter months.

You can use yellow sticky cards to monitor for winged aphids, which are a sign of either high infestation or aphid migration to your crop.

Prevention

Check surrounding areas and remove potential aphid plant hosts, such as weeds and postharvest crops. Remove any leaves that are infested with aphids.

Biological control

Natural enemies can be important for controlling aphids. Naturally occurring predators include lady beetles, parasitic wasps, lacewing larva, syrphid fly larva, and ground beetles. You can purchase lady beetles and parasitoids and introduce them early in the season to suppress aphid populations.

Chemical control

Sprays are not always necessary if predators manage the aphids effectively. Be sure to apply contact sprays to the underside of leaves.

Lepidoptera

Damage

Depending on the species, lepidopterans can damage leaves, stems, and fruit.

Symptoms and identification

Lepidopteran larvae (caterpillars), cause damage by chewing on leaves and fruit (Fig. 14). Potential lepidopteran pests of strawberries in Texas include the beet armyworm (*Spodoptera exigua*), fall armyworm (*Spodoptera frugiperda*), cabbage looper (*Trichoplusia ni*), corn earworm (*Helicoverpa zea*), cutworms, and the saltmarsh caterpillar (*Estigmene acrea*). Adult lepidoptera are nocturnal, whereas some larvae are active throughout the day.

Monitoring

Monitor for adults using pheromone traps. Monitor leaves for chewing damage or clusters of lepidopteran frass, which looks like small black pellets. Monitor before obvious signs of damage as some lepidopterans (e.g. the fall armyworm) will consume 98 percent of their total foliage intake in the last three stages (instars) of their larval development.

Prevention

Remove potential alternative hosts, such as weeds, from the area. Lepidopterans can be removed manually and discarded.

Biological control

There are many parasitic wasps and viruses of lepidopterans. Mating disruption can also be an effective strategy for managing some lepidopteran pests.

Leafrollers

Damage

Leaves and fruit.

Symptoms and identification

There are leaf roller caterpillars in Texas, but no strawberry leaf roller species have been identified. Leaf rollers are lepidopteran caterpillars in the family Tortricidae. They are chewing insects that attack leaves and even bore inside fruit. Leaf rollers cause leaves to curl with thick white webbing on the inside of the leaf, thus giving them their name.

Monitoring

Monitor for adults using pheromone traps. Monitor leaves for chewing damage, clusters of lepidopteran frass (small black pellets), or curled leaves. Open curled leaves and open webbing to search for larvae or insect frass.



Figure 14: Lepidopteran pest feeding on a strawberry. Heavy infestations can cause heavy yield losses and require producers to take control measures.

Prevention

Remove potential alternative hosts, such as weeds, from the area. Lepidopterans can be removed by hand and discarded.

Biological control

There are many naturally occurring parasitic wasps and viruses of leaf rollers. Mating disruption can also be used for managing some lepidopteran pests.

Lygus bug/Western tarnished plant bug (Lygus hesperus)

Damage

Fruit; causes cat-facing on strawberries.

Symptoms and identification

Lygus bugs use slender, straw-like mouthparts to pierce individual seeds on developing fruit. This damage halts development of the berry beneath the damaged seed(s), and can cause cat-facing. There are several species of lygus in Texas, including the tarnished plant bug (*Lygus lineolaris*), western tarnished plant bug (*Lygus hesperus*) and the pale legume bug (*Lygus elisus*). Adults are approximately ¼ inch long and are tan to brown. Nymphs are smaller, may be greenish and do not have fully developed wings.

Monitoring

Look for lygus adults and nymphs on leaves, flowers, and fruit. Another method is to place a white piece of paper or cloth beneath the plants and slap the plant material onto the white surface. The University of California has an outdoor (row crop) threshold of one lygus nymph per 20 plants when using the beat/sheet method. The threshold in strawberries is expected to be significantly lower (fewer insects can be tolerated). Insecticides are far more effective on the nymphs than on adults, so treatment should be undertaken early while most of the insects are in the nymphal stage.

Prevention

Many plants are suitable hosts for lygus bugs and they will fly to another plant when their existing host declines. Alfalfa is a very good host for lygus, and cutting alfalfa often causes lygus bugs to move on to new hosts. Lygus bugs also like to feed on wild mustards, curled dock, poppy and other species.

Biological control

There are no reliable biological control agents for lygus control in high tunnels. University of California research suggests that the parasitic wasp, *Anaphes iole*, has the potential to provide control.

Weevils

Damage

Leaves and roots.

Symptoms and identification

Weevils are beetles with two body segments and a long snout that resembles an anteater. Weevils can cause damage as both larvae and adults by chewing on the leaves. Adult female weevils lay eggs in the soil where the larvae can feed on the roots. Plants can wilt, experience stunted growth, or even be killed by larval

feeding. Weevil larvae are typically white, thick, legless, and have a curved shape around ¼ inch long.

Monitoring

Look for chewing insect damage and weevil adults. Use pitfall traps to monitor for adult populations. If plants are experiencing wilting and dieback, examine roots of plants for weevil larvae. Weevil larva populations can also be monitored by taking soil samples at the end of the harvest.

Prevention

Adults can be excluded by using barriers such as aluminum flashing with a slippery coating (Teflon) around the strawberry plants, however, larvae that are already inside the area will still develop into adults, so this strategy is not always economically feasible.

Biological control

To control weevil larvae, there are two commercially available parasitic nematodes, *Heterorhabditis bacteriophora* and *H. marelatus*. Use these parasitic nematodes early in the season in warm moist soil.

Spider mites (*Tetranychus urticae*, *T. cinnabarinus*)

Damage

Leaves, calyx and stems, indirect damage can cause slower growth, reduced transpiration, and lower yields.

Symptoms and identification

Spider mites are perhaps the most damaging pest to strawberries in Texas (Fig. 15). Spider mites are not insects. They are more closely related to spiders and are very difficult to see without magnification (Fig. 16). Their damage is often first noticed as leaf damage or webbing. Spider mites can be found on the undersides of leaves where they use their mouthparts to break open plant cells and consume the contents. Killed cells turn gray or brown. Female spider mites form colonies that spread over time, moving first to nearby leaves, fruit and stems and then to other plants.

Symptoms of significant infestation include leaf and plant discoloration, webbing, plant stunting and in severe cases, plant death. In Texas, the three species of spider mites of economic importance are the two-spotted spider mite (*Tetranychus urticae*) (Fig. 17), the carmine spider mite (*Tetranychus cinnabarinus*), and the Banks grass mite (*Oligonychus pratensis*). Most populations seen on strawberries have been the two-spotted spider mite and, to a lesser degree, the carmine spider mite. Without a microscope, all pest spider mites will look similar.

Monitoring

Spider mites can colonize plants from the time they are planted until the end of the season. Check strawberry plants for spider mites before transplanting—treat if they are present. Inspect plants weekly by examining



Figure 15: Spider mite damage (foreground) can reduce plant growth and strawberry yields. Producers must monitor for mites by scouting their plants weekly.



Figure 16: Carmine spider mites reproduce quickly and can infest strawberries throughout their entire growing cycle. High tunnel strawberries may be susceptible to mites even during the winter months.



Figure 17: This two-spotted spider mite (with egg, lower right) was found on strawberry plants during December.

leaves from several plants, including the underside and be sure to check each strawberry cultivar since mites may have varietal preferences.

A magnifying glass, hand lens or OptiVisor will help you recognize mites. Look also for webbing and brown leaves. Spider mites reproduce quickly, so weekly scouting is essential. Early detection and prompt treatment is essential to prevent wider outbreaks. Yield loss on strawberries before fruit set can be detected at one spider mite per leaflet, but after fruit set, the plant can tolerate more mites, perhaps 15 to 20 per mid tier leaflet.

Prevention

There is no way to prevent spider mites from entering a field, high tunnel or greenhouse; they can arrive in the air on silken threads. Texas pest mite species often develop on grasses and other plants, so sanitation is important. Research shows that spider mite populations tend to be greater in high tunnels than in open field production.

Biological control

Biological control agents that keep spider mites in check include the spider mite destroyer beetle (*Stethorus punctillum*), predatory spider mites that are not plant feeders, minute pirate bugs and several species of thrips, including the six-spotted thrips (*Scolothrips sexmaculatus*).

The predatory mite, *Phytoseiulus persimilis*, is commercially available and released as a biological control agent. Research in Texas has yet to determine the efficacy of beneficials for controlling spider mites in strawberries.

It may be possible to achieve some suppression, but this practice should be started before mite colonies expand. Biological control agents can be useful against spider mites, so choose insecticides and miticides that do not kill the beneficial species.

Chemical control

Most miticides take several days to act on mites. For successful control, apply miticides when the populations are small but increasing and use a miticide that will not harm the beneficial species. Avoid broad-spectrum insecticides like synthetic pyrethroids.

Spotted wing drosophila (Drosophila suzukii)

Damage

Ripening fruit.

Symptoms and identification

Spotted wing drosophila (SWD) typically lay eggs inside fruit just before harvest and the larvae eat the fruit from the inside. The fruit will soften quickly and adult flies will emerge after the fruit is spoiled. Spotted wing drosophila damage can allow secondary pests, such as fungi, to invade the fruit (it can appear that fungi was the primary pest).

Spotted wing drosophila is an invasive vinegar fly introduced to North America in 2008, through ports in California. The males have a spot on each wing at the tip of the second wing vein. The females have a serrated ovipositor. Although SWD are not yet abundant in Texas, strawberry growers in similar climates have reported fruit damage.

Monitoring

Use yellow sticky traps to look for SWD near harvest time. You can use apple cider vinegar traps as well, but they do not target SWD specifically.

Prevention

A sanitary environment is critical so remove and discard fallen or rotting fruit. If you detect an infestation, pick fruit earlier to prevent SWD from laying eggs.

Biological control

There are no known effective biological controls for SWD in North America.

Thrips

Damage

Flowers and fruit bronzing.

Symptoms and identification

Thrips are tiny and have rasping mouthparts. Their damage kills cells, but the tissue remains intact. Thrips are attracted to flowers and will damage stigmas and anthers, but research shows this damage does not interfere with fertilization. Thrips can cause bronzing on the shoulders of strawberries.

There are several species of thrips in Texas, with the most abundant being western flower thrips (*Frankliniella occidentalis*), onion thrips (*Thrips tabaci*) and tobacco thrips (*Frankliniella fusca*). You may expect to find any of these species on strawberries in Texas. Thrips are very small, yellow to brownish insects that are difficult to see on plants. Adults and immature stages look alike except that adults have thin, feathery wings. Thrips look like tiny whiskers in the bottom of the sink.

Monitoring

The best way to monitor for thrips is to shake flowers onto a white piece of paper and count the ones that fall off. When using this method, University of California research suggests treating thresholds of ten thrips per flower. Another method is to remove and shake flowers in to a solution of alcohol and count the thrips that fall to the bottom of the container.

Prevention

Thrips can live on many different hosts and they usually move when the host declines. In Texas, large numbers of thrips take flight in the spring when wheat and other early season hosts begin to dry. Given their small size, exclusion seems ineffective. Western flower thrips are predators of spider mite eggs and can be considered beneficial in high tunnels as long as they remain below damaging levels.

Biological control

There are no reliable biological control agents to control thrips. A general release program of predatory insects (e.g. minute pirate bugs) may lower overall pest insect levels, including thrips.

Chemical control

There are effective insecticides for thrips, but avoid broad-spectrum insecticides like pyrethroids that may kill beneficials and facilitate spider mite outbreaks.

Whiteflies (*Bemisia spp.*)

Damage

Leaves and fruit indirectly.

Symptoms and identification

Whiteflies are sucking insects. Leaves can yellow, wilt, and have small yellow spots or appear dry in heavy infestations. Sticky or shiny residue on leaves can be an indication of honeydew secretions from whiteflies. Honeydew can also act as an inoculant for fungal growth (e.g. sooty mold). Whiteflies can vector plant viruses and pathogens.

Adult whiteflies are yellowish with whitish wings. Adults lay oval eggs, often in a circular pattern. The first instar nymphs that emerge from the eggs, known as crawlers, are small scale-like insects that are flat and ovular and often stay still once they find a good spot to feed. Although still small, older nymphs are larger and easier to recognize. Pupae are yellowish and have two red eyes that are visible through the cuticle.

Monitoring

Check the underside of leaves for clusters of whitefly nymphs and watch for flying adults. Feel for sticky residue. Ants can be a sign of whiteflies because they farm whiteflies for their honeydew.

You can use yellow sticky traps to detect whiteflies when they migrate in or move within a greenhouse. Sticky traps can indicate the level of infestation, though the number of whiteflies on the sticky cards may not correlate to number of nymphs on the strawberry plants.

Prevention

Control or remove nearby plants that can attract whiteflies. Topping strawberries near the beginning of the season can help decrease overwintered populations. Control whitefly populations even after harvest in order to reduce populations for next season.

Biological control

Lacewing larvae, parasitoids from the genera *Encarsia*, *Eretmocerus*, and *Prospaltella* are effective predators—they are commercially available for whitefly control.

Grasshoppers

Damage

Leaves, stems, flowers and more rarely, fruit.

Symptoms and identification

Grasshoppers use their mandibles to chew any type of plant tissue. Though they prefer the leaves, large grasshopper populations can damage other parts of the plant. Caterpillars also have mandibles and their damage can look similar.

Grasshopper leaf damage often begins on the outside edge and progresses inward. Caterpillars often begin in the middle of the leaves. It is usually not important to identify the grasshopper species because damage and control practices are the same for most of them.

Monitoring

Grasshoppers deposit eggs in the soil. Immature grasshoppers (first instar) are small and difficult to detect. However, they are usually discovered during monitoring because they move when disturbed at all life stages. Small nymphs do not cause much damage, but they must be controlled before they become older nymphs or adults.

Prevention

Exclusion is the best way to prevent grasshopper problems. Controlling or eliminating weeds outside the field or high tunnel will keep grasshoppers from being attracted to the area.

Biological control

Predators include blister beetles and robber flies, but no commercially available predator provides sufficient control.

Chemical control

Some insecticides are effective for grasshoppers. However, they should be used when the insects are small because they are less effective on large grasshoppers.

Protecting pollinators

Strawberries are self-pollinating; they have male and female reproductive parts within the same flower. As a result, approximately 80 percent of strawberry pollination can occur through gravity or wind. However, honeybees, bumblebees, flies, etc., can increase yields. You can encourage these pollinators by avoiding harmful pesticides when strawberries are flowering. You can also plant flowers nearby that attract pollinators early in the season.

Disclaimer: This NSSI publication was released while strawberries in high tunnels were still a new technology in Texas, as well as in open field trials. Pest control strategies have yet to be tested for efficacy. As such, these biological and chemical control strategies are suggestions and are not guaranteed.

Also note that according to the Texas Department of Agriculture (TDA), pesticides labeled for field use may not be sprayed inside high tunnels unless the side ventilation systems, door and windows are open and remain so during the full Reentry Interval (REI) of the sprayed chemicals. Contact the TDA for additional clarification.

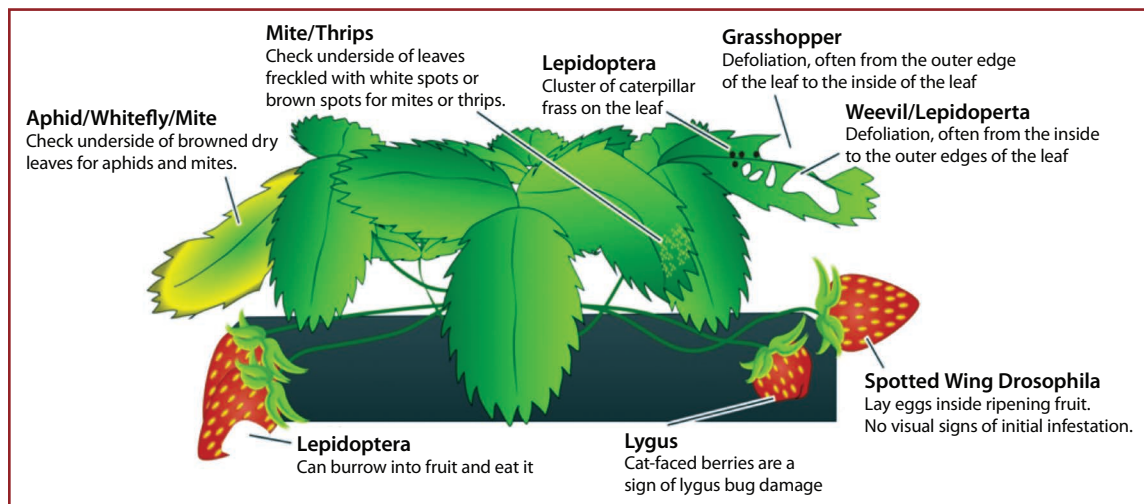


Figure 18. Type and location of damage caused by major insect pest groups of strawberries in Texas.

Diseases

Molly Giesbrecht and Kevin Ong

Disclaimer: The fungicidal chemicals mentioned in this guide are labeled for use on strawberries for the diseases listed below as of (June 2014). Always check the most up-to-date information and always follow labels to determine proper application rates and intervals. Contact your county Extension office for further guidance. <http://agrilife.extension.tamu.edu/>.

Powdery mildew

Biology and symptoms

Powdery mildew on strawberry, caused by the fungal pathogen *Podosphaera aphanis* (syn. *Sphaerotheca macularis*), infects the flowers, leaves, and fruit of the plant. Fungal infection and spread is helped by high humidity and temperature of 60 to 80°F. Overhead irrigation, rain, and dew inhibit the development and spread of this disease, so this pathogen tends to cause more problems in greenhouses and high tunnels.

Infection on flowers can prevent fruit maturation or cause berries to be malformed. Infection on the berries, especially during early development, can reduce quality and yield. White, powdery spores appear on infected fruit. Infected leaves start with white patches on their undersides, but can become solid white underneath and the leaf curl upward, turn red to brown and die.

The fungus overwinters as resilient structures, which can remain dormant until suitable conditions return. The fungus is host specific and is unable to survive without a host tissue. The fungus is typically introduced to new areas through infested nursery stock.

Management

Ensure that transplants are disease-free before planting. Purchase plants from reliable sources and inspect them for any signs of infection. When outside conditions are suitable for plant growth, raising the sides of high tunnels will improve air circulation and reduce inside humidity.

Fragaria virginiana ssp. *Grayana*, and *F. virginiana* ssp. *virginiana* have limited resistance to powdery mildew. Varieties 'Festival' and 'Radiance' are susceptible to the disease. Fungicides labeled for controlling powdery mildew include myclobutanil, propiconazole, tetraconazole, quinoxyfen, penthiopyrad, and combination products with pyraclostrobin, or boscalid.

Botrytis

Biology and symptoms

The fungus *Botrytis cinerea* infects leaves, flowers, and fruit of strawberry plants. Leaf infection is usually not significant but it leads to infection of other tissues. Infection often starts on dying leaves as a dense, gray fungal growth. The spores spread to young leaves, flowers, and fruit through the air or by rainfall or overhead irrigation. High humidity promotes fungal development.

The fungus infects flowers, but often only becomes active when berries are nearly mature or after harvest (Fig. 19). Like the leaves, infected berries develop a dense, gray fungal growth that



Figure 19: Botrytis grey mold is prevalent in all environments and especially during cool, wet weather. Higher humidity levels in high tunnels may increase berry infection.

can spread to nearby fruit. This fungus is widespread and overwinters as sclerotia in the soil or on dead plants.

Management

Botrytis infection is prevalent throughout the environment—it is important to prevent and control it using fungicides during bloom and when conditions are favorable. Promoting air circulation in field production and raising the sides in high tunnels will help to avoid disease development. Plastic mulches can insulate plants from contact with fungus residing in the soil. Removing plant debris at the end of each growing season will reduce infection the following season. Effective fungicides for *Botrytis* include tetramethylthiuram disulfide, fenhexamid, thiophanate-methyl, and combination products containing pyraclostrobin and boscalid or fludioxonil and cyprodinil.

Colletotrichum diseases

Biology and symptoms

Colletotrichum spp. are fungi which cause crown rot, stem lesions, leaf spot, flower blight, and fruit rot in strawberries. This disease prospers in high humidity at and above 68°F. Spores spread through the air and by rain splash. Crown infections appear as sunken, necrotic lesions and typically go on to kill the entire plant. Blossom infections lead to aborted flowers that decrease the fruit yield. Infections on berries begin as water-soaked, light brown spots that develop into dark brown to black round lesions with salmon-colored spore masses. Necrotic spots also develop on infected leaves.

Management

It is critical to ensure that newly introduced plants are free of *Colletotrichum* diseases. Protectant fungicides can prevent infections but will not control existing infections. Avoid overhead irrigation, remove infected plants or plant parts, and use low nitrogen fertilizer to help manage this disease.

Phytophthora diseases

Biology and symptoms

The fungi *Phytophthora* generally cause problems in wet or poorly drained soils, though some species can attack strawberries regardless of conditions.

Phytophthora citricola and *P. fragariae* cause root and crown rot, and red stele root rot, respectively. *P. cactorum* may cause crown rot and fruit rot of strawberry, with the latter often referred to as leather rot.

Other *Phytophthora* species may affect strawberry, but do not cause disease as frequently. With *Phytophthora* spp., the symptoms often include dieback, and leaf or stem chlorosis. Symptomology may differ slightly according to species (Fig. 20).

Root rot from *P. fragariae* causes a red discoloration of the stele (core) of the root. *P. citricola* is aggressive and may kill the plant rapidly. Other *Phytophthora* species cause problems only in low-lying areas where water drains poorly. Injury at planting may allow the pathogen to gain entry through the wound.



Figure 20: Strawberries are susceptible to root diseases. Some of these diseases may spread through irrigation water.

Leather rot (*P. fragariae*) can cause severe losses. Fruit may become infected at any stage, turn brown and have a leathery texture. The disease can include a white mycelium on the fruit surface. Infected berries also develop a disagreeable odor and taste. The pathogen spore is spread by soil, water or by rain splash. Spores can remain in the soil for extended periods and cause infections the following season.

Management

Managing *Phytophthora* pathogens typically combines cultural and chemical controls: using disease-free plants, improving drainage on poorly drained sites with drainage tiles or raised beds, planting resistant cultivars, and applying fungicides including metalaxyl, phenylamides, and fosetyl-al.

Other foliar pathogens

Biology and symptoms

Common and destructive foliar diseases of strawberries include leaf scorch (*Diplocarpon earlianum*), leaf spot (*Mycosphaerella fragariae*) and leaf blight (*Phomopsis obscurans*). These diseases are caused by fungal pathogens with spores spread in the air and/or by rain splash.

Leaf symptoms for all three diseases begin as small, purplish spots or blotches. With *D. earlianum*, the spots enlarge, coalesce and the leaves turn brown. This leads to marginal leaf curl and necrosis. With *M. fragariae* infections, the leaf spots enlarge to about 6 mm with centers that turn a light tan color. *P. obscurans* leaf spots will enlarge to become elliptical to V shaped along major veins and older spots will develop dark brown centers surrounded by a light brown margin, then a chlorotic to red or purple halo.

Management

Using disease-free plants is the first step. When appropriate, fungicide applications can help; the timing and specific fungicide used depend on the severity of each disease. There are cultivars that are resistant to *D. earlianum* and *M. fragariae*. With *D. earlianum* and *P. obscurans*, removing dead plant debris at the end of the season will help prevent transmitting infection to future growing seasons.

Weed Control

Russ Wallace and Joe Masabni

Weeds compete with strawberries for moisture, sunlight, space, and nutrients. They harbor insects and diseases that attack the plants and berries. They also inhibit pollination by wind or bees. Strawberries are a low-growing crop and are shaded by weeds taller than 12 inches.

Plastic mulches suppress weeds close to strawberry plants and keep most weeds from competing. However, plastic mulch cannot keep yellow (*Cyperus esculentus*) or purple nutsedge (*Cyperus rotundus*) from emerging and puncturing through. Fields with dense stands of these weeds should be avoided.

Hand weeding early in the season is critical for establishing the crop. Most fields require repeated hand weeding to reduce competition and increase yields—you will need sufficient labor throughout most of the growing season. Keep the first 40 days after transplanting generally weed free. By then, the strawberry plants should have established and reduce weed germination by shading the planting hole.

It is critical learn the field history and identify the major weeds before transplanting strawberries. Annual weeds are easier to control than perennials; your County Agent can help you identify them.

Most high-production fields in California and Florida use preplant fumigation to control weeds, soil insects, and disease pests. Fumigation cost, however, is generally prohibitive for small-scale production. You can selectively control weeds with herbicides before or after transplanting. Post-plant herbicides can be used for in-furrow weeds that escaped preplant treatments. Always read and follow all the herbicide label instructions. This ensures human and environmental safety, and confirms the herbicide is appropriate for the target weed.

Weed management should combine prevention (using weed-free transplants and plastic mulch), sanitation (cleaning equipment and tools between fields), cultural practices (crop rotation, cover crops), mechanical control (cultivation and hand weeding), and chemical control (herbicides). In organic production systems, soil solarization with plastic mulches can be an effective alternative to herbicides. Using multiple tactics will increase overall weed control. Weed control requires constant vigilance—the ideal time to deal with weeds is when they are less than 1 to 2 inches tall.

Harvesting and Handling Strawberries

Russ Wallace and Juan Anciso

The peak harvest period for strawberries in Texas generally begins in the early spring and continues through the end of May or early June. This can vary somewhat by planting date and location. The production system also influences the days to first harvest. Research on the High Plains shows that strawberries planted in September will begin to produce ripe berries by the end of December when grown in high tunnels—ripe berries in open field production did not occur until April. When transplanted in late October or early November, the colder temperatures will delay the first harvest until early spring, especially in northern regions.

Harvests during the winter months will be lower than during the peak harvest season. Strawberry growers in the High Plains and Panhandle regions should use high tunnels, as these will increase quality and yield. Growers in central Texas may want to delay planting until cooler night temperatures allow for adequate growth. Those growing in southeast and south Texas should wait until average daytime temperatures are less than 85°F to avoid leaf scorching.

Black plastic mulches coupled with drip irrigation and row covers will increase strawberry growth and allow earlier harvests (Fig. 21). Black plastic warms the soil root zone and speeds up plant development. Clear plastic or Spunbond row covers can also improve plant growth by warming the air around the plants creating a greenhouse-like atmosphere. Row covers also improve yields by protecting developing fruit from freezing temperatures. However, disease and insect pests must be monitored closely.

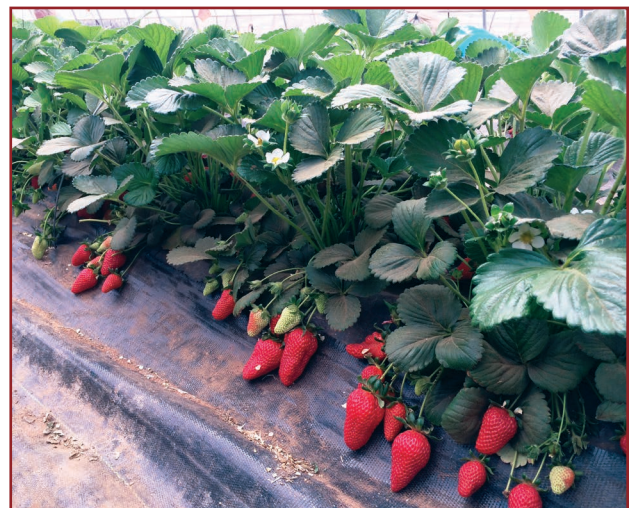


Figure 21: Plastic mulch coupled with drip irrigation will cause crops to produce earlier and improve overall yield and strawberry quality.

All strawberries are harvested and packed by hand. Using raised beds will reduce bending when picking berries; and during peak season, the berries may need to be harvested daily. Strawberries do not ripen once picked so they should be harvested when the fruit is more than 80 percent red. Berries should be pulled carefully off the plant without taking the stem or damaging nearby stems and leaves, or other berries. When fruit is packed, stems left on the berries can damage other fruit and promote disease.

Strawberries should not be packed too deep or they may bruise and cause berry rot. Berries that are not consumed within a few hours should be placed in protective containers and cooled to about 34°F. For coolers with ice or dry ice, place a barrier of Styrofoam or wax paper between the ice and strawberries to keep them dry. At approximately 34°F the berries can stay fresh for up to a week.

Do not leave harvested berries in the sun, especially in hot, dry conditions. If no coolers are available, put harvested berries in a shady area or harvest in early morning or late evening. Never wash berries for storage or sale; this increases the potential for disease and decay. Storage quality varies because some varieties produce softer berries than others. A firmer berry generally stores longer. The harvested berries should be transported immediately or sold to consumers.

Food Safety on the Farm

Juan Anciso and Russ Wallace

Food safety begins on the farm. The acronym GAPs stands for Good Agricultural Practices; these practices help prevent microbial, chemical and physical contamination of fresh produce from planting to harvest. Microbial contaminants include viruses, bacteria and protozoan parasites that can cause human illness. Sources for these contaminants include animal feces, irrigation water and handling the strawberries. Understanding and following the good agricultural practices listed below will help you avoid contaminating your strawberries.

Hygiene

Always wash your hands properly before handling strawberries. Microbial contamination is a leading cause of food-borne illness and can be prevented by proper hand washing. This means using potable water, scrubbing palms, backs of hands, between fingers and under nails with soap for at least 20 seconds and then drying with a single-use towel. Use the towel to turn off the water and open the door. Reciting the ABCs twice takes about 20 seconds.

Irrigation water

Water is a key source for spreading contamination. Make sure you know your water source; for municipal water, consult annual water reports. Other water sources such as wells and surface water should be tested for by a certified laboratory.

Fertilizer

Synthetic fertilizers don't pose microbial contamination risks, but organic fertilizers such as compost must be completely processed and not contain any

raw manure. Plant-based composts are considered safer than those from animal byproducts.

Animal encroachment

Animal feces is another major source of produce contamination. Monitor your strawberries for any wild or domestic animal intrusion. Use fencing, nets, or traps if necessary.

Sanitation vs. cleaning

Cleaning refers to washing or removing debris from an item or surface. Sanitation refers to the use of a product that can reduce or kill unwanted microorganisms. Use sanitizers safely.

Equipment sanitation

Clean equipment prevents the spread of contaminants from one plant or product to another. Clean and sanitize clippers and harvest containers after each use, then store them where they will not be contaminated.

Pest control

Monitor the use of synthetic or organic chemicals in your strawberries. Make sure only knowledgeable staff apply them. It is also a good idea to keep a log of each time they were used, how much was used and who applied it. Organic pest control chemicals can be harmful if not used properly. Do not assume organic or natural products are safe.

Visitors

Make sure that any visitors or pick-your-own customers follow all the same rules that you do such as proper hand washing.

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