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High Tunnel Strawberry Production

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Introduction

Fresh local strawberries are always a favorite at farmers' markets and roadside stands. Strawberries grow best at temperatures around 70 to 75˚F. Utah's cold winters and hot summers provide only a short strawberry season. Greenhouses are designed to maintain optimal growing temperatures, and can be used to grow strawberries year round. However, greenhouses are expensive to both build and operate. High tunnels are relatively inexpensive to build, with some designs costing less than $0.50 per square foot (Black et al., 2008a). Since high tunnels are passively heated and cooled, operating costs are minimal. However, many of the benefits noted for greenhouses, such as early spring and late fall harvests, and better summer production, are realized. High tunnels have effectively extended the strawberry growing season in Utah's Cache Valley from early May to mid December.

Plant Selection

Strawberries have three fruiting habits. **June-bearing** strawberries initiate flowers under short day conditions in the fall. The flowers open the following spring and produce fruit for about a 4 to 6 week period. In northern Utah, this season is generally from mid May to mid June. **Everbearing** strawberries initiate flowers under long day conditions and generally produce a small crop in the spring with a more substantial crop in the fall. **Day-Neutral** strawberries produce flowers regardless of day length, as long as temperatures are between 40 and 85˚ F (Hancock and Handley, 1998). In many production systems, Day-Neutral and everbearing strawberries show similar production patterns and these names are sometimes used interchangeably.

Table 1. Strawberry varieties tested for Utah high tunnels.

Day-Neutrals	Berry Size	Uniformity	Heat Tolerance	Cold Tolerance	Grey Mold Resistance	Flavor
Albion	Good	Excellent	Poor	Excellent	Excellent	Excellent
Evie 2	Excellent	Good	Excellent	Poor	Poor	Moderate
Seascape	Good	Good	Moderate	Good	Good	Good
Tribute	Poor	Moderate	Good	Moderate	Poor	Poor
June Bearers						
Chandler	Good	Good	NA	NA	Good	Good

The marketing and management goals of individual operations should dictate what type of strawberry plants are grown. If the single objective is to obtain price premiums for the earliest local strawberries, fall-planted June-bearers in high tunnels will produce the earliest large crop, with significant production 4 weeks earlier than outdoor field grown plants. In Cache Valley this results in harvests in early- to mid- May. However, if a farmer wants the longest possible production season, day- neutral varieties will continue to flower and fruit indefinitely, as long as appropriate temperatures are maintained in the high tunnel. Table 1 lists some varieties that have been tested in Utah high tunnels and some of their characteristics.

Yields

High tunnels can significantly extend the growing season for strawberry production in Utah. As a general rule of thumb, high tunnels fall planted with June Bearing varieties can be expected to come into production about 4 weeks earlier than field production. High tunnel day-neutral varieties on the other hand have been shown to extend the season into late fall. Figure 1 shows some general yield trends observed at the high tunnel research trials conducted in Logan, Utah, during 2008. Table 2 gives more detailed yield information for specific strawberry varieties tested in Utah high tunnels.

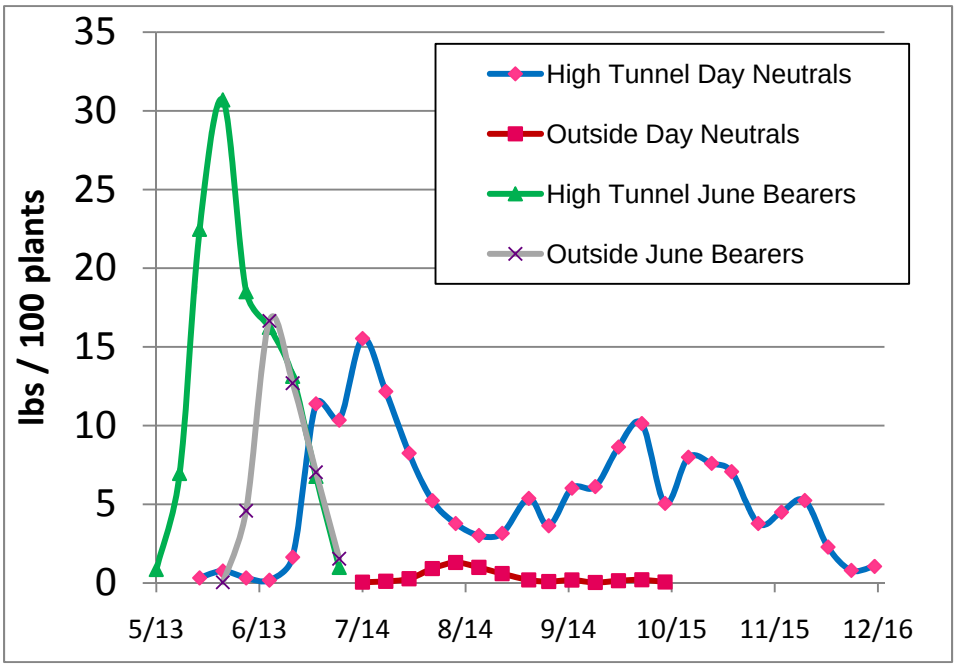

Figure 1. Yield trends for Logan, Utah, high tunnels 2008 and 2009 data.

Site Selection

Strawberries perform best in well drained sandy or loam soils. The use of raised beds can increase soil drainage in any type of soil and are strongly recommended when planting strawberries in heavier clay soils. Alternatively, strawberries can be grown in containers or in bags filled with potting mix on top of the ground. Raised beds also cause soils to warm earlier in the spring resulting in earlier fruiting and make fruit harvest easier. Strawberry high tunnels should be located in an area that is not subjected to shading, particularly on the south and west sides of the high tunnel, so as to maximize solar radiation capture in the early spring and late fall. The high tunnel should also be located near a year-round water supply in order to facilitate

Table 2. High tunnel yield breakdown for strawberry varieties. Yields are shown in lbs/100 plants.

	Pre-Season	In-Season	Post-Season
June Bearing			
Chandler	79	37	
Day Neutral			
Albion		87	30
Evie 2		139	34
Seascape		116	45
Tribute		101	36

irrigation in the early spring and late fall when seasonal irrigation water is not available.

In order to prevent buildup of soil borne pathogens, strawberries should not be planted in the same soil for more than 5 years without using some type of fumigation. For small scale farmers who grow a variety of crops, the best option is to use crop rotations. However, care should be taken so that strawberries do not follow tomatoes, potatoes, eggplant, peppers, or okra in a crop rotation, as these crops harbor the verticillium wilt pathogen.

Site Preparation

Before planting strawberries, soils should be tilled to a depth of 6 to 12 inches. Organic material such as compost is always helpful and can help alleviate replant and drainage problems as described above. After working the soil, planting beds should be formed, drip tape for irrigation installed, and plastic mulch laid on the bed.

Management Systems

There are two main management systems in strawberry production; the matted row system, and the annual hill system (Black et al., 2008b). The matted row system is a perennial system for producing June Bearing strawberries in colder climates and works well in outdoor field production in Utah. However, this system is not well suited for high tunnel production. We recommend the annual hill system for high tunnel strawberry production, as this provides the earliest yields and the highest quality fruit. For the annual hill system, plants are spaced 12 to 15 inches apart in the row, with staggered rows spaced 12 to 15 inches apart (Figure 2). Runners are removed so that only the mother plants grow and produce fruit. Beds are generally 2 to 4 rows wide, with each row being approximately 1 foot wide. Thus a two row bed would be 2 feet wide, and a four row bed would be 4 feet wide. Beds can be level with the remaining ground or can be raised. Raised beds improve drainage, and are highly recommended for heavier clay soils and earlier yields. Raised beds are typically 8 to 12 inches tall and covered with black or white plastic mulch. Black plastic mulch tends to warm the soil sooner in the spring and keeps it warmer later into the fall. White plastic, on the other hand, tends to keep plants and soil slightly cooler during the heat of summer. With June bearing strawberries, black plastic mulch is recommended because strawberry plants are usually removed before the hottest part of the summer and new plants are planted after the hottest part of the summer is past. White plastic mulch might be considered for day-neutral varieties, depending on the

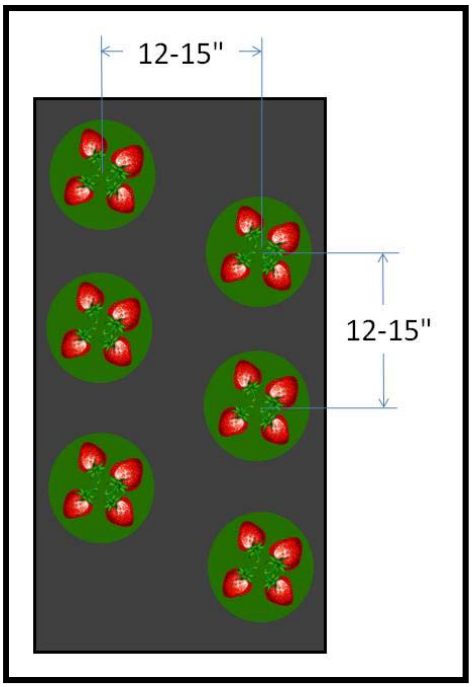

Figure 2. Strawberry planting bed.

goals of the individual operation. If there is more focus on better summer production, white plastic would be a good choice. However, it the focus is on early plant establishment and late season extension, black plastic mulch might be a better choice. In addition to its effect on plant/soil temperature, plastic mulch also helps control weeds. However, the use of plastic mulch requires that drip tape be placed under the plastic to facilitate irrigation. In order to obtain the highest yields and quality every year, plantings are generally replaced on an annual basis.

Plant Establishment

June Bearers are typically planted as "plug plants" the fall before production is desired. In colder climates such as Cache Valley, planting should take place about the first of September, with later planting in warmer climates such as central or southern Utah. Experimentation with the planting dates may be needed to determine the optimum planting dates for individual locations. Plug plants transplanted too early will produce excessive runners and too many branch crowns on each plant. Late plantings results in inadequate plant establishment and insufficient branch crown formation. The ideal transplanting date will result in a vegetatively-balanced plant with 4 to 6 branch crowns at harvest. Plug plants are recommended for use in high tunnels for fall planted June bearing varieties; however, bare root plants can be used in place of plug plants if necessary, but typically they need to be planted three to four weeks earlier than plug plants.

Finding a source for either plug plants or dormant bare root plants in September is difficult. However, some nurseries will hold dormant stock for late summer plantings if ordered well in advance. Also, strawberry plug plants can be readily propagated in a greenhouse. For more information on propagating strawberry plug plants, see the USU factsheet *Propagating Strawberry Plugs.*

Day-Neutrals can be fall planted with plugs or dormant plants, but also can be planted in late winter using dormant bare root plants. In tunnels in Cache Valley, plantings have been achieved as early as February. Warmer climates allow for earlier plantings. The most important thing to remember is that the plants will start to grow anytime the temperature is above 40°F. Therefore, plants should be established as early as possible in an effort to maximize yields. The use of a low tunnel placed within a high tunnel is an effective way to encourage growth on winter planted day-neutral plants, as the low tunnel provides more protection on cold nights and more ideal temperatures on cooler days than high tunnels alone (Figure 3).

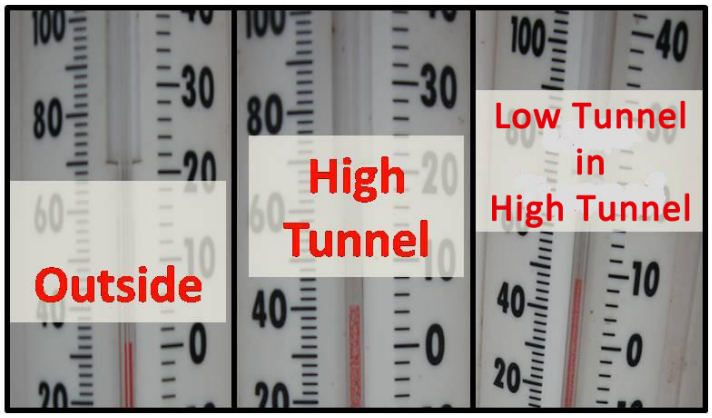

Figure 3. Temperature differences on a cool overcast morning.

Fertilization

Plant nutrition is best accomplished through fertigation, or applying fertilizer in the irrigation water, using an injector system. A high quality mechanical injector is strongly recommended. Dosatron® and Chemilizer® brands have both been used with success. Fertigation will allow growers to apply fertilizers in small amounts every time plants are watered. Fertilizer rates vary among soil types according to nutrient holding capacity. Plant nitrogen (N) requirements can be determined by observing the vegetative vigor of the plants. Overly vigorous plants will have large, dark green leaves with long petioles and appear too bushy. In the loamy soils at the USU Greenville research farm, we have found the following fertilizer regime to be effective. During the vegetative growth stage of the strawberry plants (fall and early spring for fall planted June Bearers; or spring and early summer for winter planted day-neutrals) a 20-20-20 N-P-K plus micronutrients is applied at a rate of 100 ppm N with every watering cycle. Once the plant starts to produce flowers, a 10-20-10 mix is used at 50 ppm N with every watering cycle. For day-neutrals, the 10-20-10 mix at 50 ppm N is applied throughout the remainder of the season. However, in June bearing varieties, once the first berries start to ripen, a 10-30-20 fertilizer (25 ppm N) is injected at every irrigation. When selecting a fertilizer source, consult your vendor to be sure the selected mix can be mixed with water without forming precipitate, which will cause problems with the injector and plug the drip tape emitters. One of the most common nutrient deficiencies for strawberries in Utah soils is Iron. Iron chlorosis is characterized by interveinal yellowing (see USU fact sheet *Iron Chlorosis in Berries*). A chelated iron such as Miller's Ferriplus or Sequestrene 138 should be applied as needed according to the rate listed on the label.

Tunnel Management

High tunnels capture and retain heat. The first goal when using high tunnels is to protect the fruit and flowers from frost injury in the early and late parts of the year. This means keeping the temperature above 28˚F, especially when there are fruit and or flowers on the plant. The second goal is to keep the temperatures in the tunnel warm enough for the plants to continue growing. The minimum temperature at which strawberry plants continue to grow (baseline) is about 40°F. The third goal is to maintain optimal temperatures for as much of the day as possible. The optimal temperature for strawberry growth is between 70 and 80 degrees. Tunnels should be vented during the day in order to avoid temperatures above 80 degrees, and should be closed in the early evenings or on colder days in order to maintain temperatures within or as close as possible to the optimal range (70 to 80 degrees). A simple thermometer is a valuable tool to help growers determine when to vent and when to close their high tunnels.

Low Tunnels (Figure 4) placed within the high tunnels are another tool for out of season strawberry production. Low tunnels are typically only 12 to 18 inches tall and about 30 inches wide, just large enough to cover a single strawberry bed. Low tunnels can be constructed by bending ½″ conduit so that it spans the strawberry bed and is slightly taller than the canopy. These arches are placed every 5 to 10 feet, and twine or other light rope is stretched between the arches and tightened to support the plastic above the strawberry plants. Low tunnels can be used in conjunction with high tunnels in the spring and fall to encourage earlier and later flowering and fruit

Figure 4. Low Tunnels within a High Tunnel.

development. Additionally, low tunnels can be used with winter planted day-neutrals to help increase early plant growth, which will lead to earlier and higher yields. High tunnels generally provide a 3 to 5 degree temperature lift over outside conditions during the night. However, when combined with low tunnels, another 3 to 5 degree lift can be expected. Low tunnels can also be used on cooler days to lift the temperature into the optimal range (70 to 80 degrees) when high tunnel temperature doesn't reach this optimal threshold. However, extreme caution should be used with low tunnels as they have a tendency to heat up very quickly and can lead to plant damage if not managed properly. As a general rule of thumb, on a sunny day, high tunnels alone can be expected to yield a 30 degree temperature lift over outside conditions. When low tunnels are used in conjunction with high tunnels, another 10 degree temperature lift within the low tunnel is usually realized. A good practice is to uncover low tunnels and vent high tunnels during the daylight hours, and then recover low tunnels and close high tunnels during the night to retain warmth.

Pests

Grey Mold is perhaps the biggest problem for high tunnel strawberry production (Figure 5). The fungal pathogen thrives in the warm humid environment found in high and low tunnels. Infection of the fruit can be avoided with timely applications of a fungicide such as Captan. The infection typically occurs during bloom, then remains latent until the fruit begins to ripen. Additional infections which damage the plant may occur over the winter and these should be treated as needed. Grey mold is generally not a problem in spring strawberries in Utah, as the tunnels are generally open during the day and the humidity level remains low. However, grey mold can be a significant problem with fall crops, when cold fall weather requires the tunnels to be kept closed for extended periods of time during bloom and fruit development. It is recommended that fungicide applications be made regularly beginning approximately 4 weeks before the tunnels are expected to be closed for extended periods of time.

Other Pests may include Spittle Bug, Aphids, and Spider Mites. Spittle Bugs create a bubbly liquid mass that is often found on the leaf petioles. Spittle bugs can be treated with a variety of insecticides such as Malathion, but may need to be treated after the high tunnel plastic is removed for the summer. However, Spittle Bugs do not generally cause significant amounts of damage with low population numbers, so treatment may not be warranted. Aphids and spider mites may also be occasional pests. Aphids and spider mites can be treated and controlled with insecticidal soap (DeFrancesco, 2008).

Harvesting should be carried out every 2 to 3 days to ensure maximum quality. Berries should be harvested when neither the tip nor the shoulders are still green or white. After the fruit is harvested, it should be refrigerated promptly to maintain quality.

Insect pollination is not necessary to produce strawberries, as fruit develop without being pollinated. However, allowing insects to pollinate strawberry flowers will help increase the size of the berries. Honeybees are not typically good pollinators in high tunnels as they use ultraviolent light (UV light) to navigate and are unable to "see" under most greenhouse plastics. However, bumble bees and alfalfa leaf cutter bees are commercially available and work well in high tunnels.

Figure 5. Grey Mold.

Summary

Fresh, locally grown strawberries are always a favorite at farmers' markets and other local retail outlets; however, fresh locally grown strawberries are rare in Utah. The use of high tunnels for strawberry cultivation gives local farmers another option that may help them economically produce to grow strawberries for an extended strawberry season, thus making commercial strawberry production an option, where it might not have been viable in the past. High tunnel strawberries should give local farmers the opportunity to market fresh locally produced strawberries to the public and charge premium prices for a product that is both rare and out of season.

Additional Resources

Black, B., G. Cardon, and C. Ransom. 2009. Iron Chlorosis in Berries factsheet http://extension.usu.edu/files/publications/publication/Horticulture_Fruit_2009-02pr.pdf

Black, B., D. Drost, D. Rowley, and R. Heflebower, 2008. Constructing a Low Cost High Tunnel http://extension.usu.edu/files/publications/publication/HG_High Tunnels_2008-01pr.pdf

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