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High Tunnel Strawberry Production for Late Fall Harvest

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Introduction

Strawberries grow best at temperatures around 70-75˚F, and blossoms are damaged when temperatures dip below 30˚F. Utah's cold winters and hot summers provide only a short period when conditions are optimal for strawberry growth, and freeze events can limit production below economic levels. High tunnels can extend the period of optimal temperatures and protect blossoms from damage. High tunnels can be built at relatively low cost and are passively heated and cooled, keeping operating costs minimal. Visit tunnel.usu.edu for more information on high tunnel construction and management. Utah State University Extension researchers have developed two systems for high tunnel strawberry production. This fact sheet details an early spring-planted, fall-harvested system. A fall-planted, spring-harvested system is detailed in a companion fact sheet. All research was conducted using USU's low-cost high tunnel design.

Planting System

High tunnel space is valuable and usually limited. It is important to use a growing system that will be the most productive and profitable per square foot. In an annual hill system (Figure 1) plants are planted into raised beds, usually 8-12 inches high, and are removed after one season. This capitalizes on the most productive one-year-old plants. 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 is strongly recommended when planting strawberries in heavier clay soils. Raised beds make fruit harvest easier and cause soils to warm earlier in the spring and later in the fall, resulting in extended fruiting. The beds are drip irrigated and covered with plastic. Black plastic mulch warms the soil, conserves water, and minimizes weeding. In the annual hill system, runners should be removed so the plant focuses all of its energy on root, crown, and flower production.

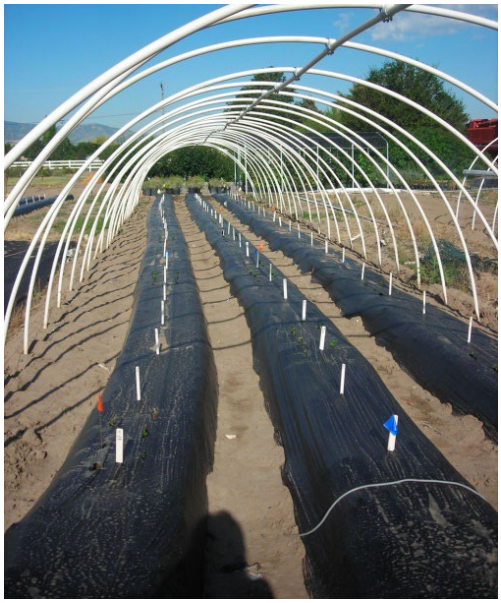

Figure 1. Raised beds, ready for planting annual strawberries. Beds are 8-10 inches tall, 24 inches wide and covered with plastic mulch.

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 4-6 week period.

In northern Utah, this season is generally from mid-May to mid-June. **Ever-bearing** strawberries initiate flowers under long day conditions, whereas **day-neutral** strawberries initiate flowers regardless of day length, as long as temperatures are between 40 and 85˚F. Because mid-summer daytime temperatures in many areas of Utah exceed 85˚F, both day-neutral and ever-bearing strawberries produce a spring crop and then a small crop in the fall, but do not fruit in midsummer. For fall-harvest, day-neutral strawberries should be used.

Plant Type and Planting Date

Dormant or plug plants can be used for early spring planting (Figure 2). Bare-root dormant plants are dug in the late fall or winter and are readily available in the early spring. Plugs are actively growing rooted plants. They can be purchased or produced on your own. The USU Extension fact sheet Propagating Strawberry Plugs provides a step-by-step guide for production. Dormant plants are less expensive than plug plants and have performed well in Northern Utah high tunnels. In North Logan (elevation 4692, latitude 41.735 N), dormant plants were planted in late February. Planting date should be adjusted depending on location. Optimum plant establishment produces about four to five branch crowns per plant by the start of the harvest season in July.

Figure 2. Bare-root dormant plant (right) and actively growing rooted plug plant (left).

Fall Preparation

In order to be prepared for planting in the very early spring, raised beds (described previously) should be formed in the late-fall since soil conditions in February are typically not suitable for cultivation. Additionally, high tunnel plastic should be installed at this time to keep rain and snow from saturating the soil. If plastic installation is delayed until after fall rain or snowstorms, the moisture will be trapped inside the tunnel and is difficult to dry out once temperatures drop. Excessive moisture can lead to increased disease incidence.

If heavy snow fall is common in your area, be sure to select a tunnel design that can withstand snow load. Alternatively, snow supports may be needed (figure 3) for PVC-frame tunnels to prevent the collapse until the snow can be swept off.

Figure 3. Low tunnels over raised beds inside a high tunnel. Snow supports are the wooden 2x4s in the middle row.

Establishment and Spring Care

Early spring irrigation in a Utah high tunnel is typically from a culinary water source, as secondary irrigation water is usually not available. Freeze-free faucets are critical, and hoses should be drained after each use to avoid freezing. It is important to keep adequate soil moisture during establishment. Under Northern Utah soil and weather conditions, this required one irrigation event per week initially, and increased to two times per week as the plants grew larger and temperatures warmed. Depending on cultivar, plant type, and planting date, the plants may begin to send out runners that should be removed. Dormant bare-root plants will also send out an initial flower cluster which needs to be removed to promote root and crown establishment.

Tunnel Management

High tunnels capture and retain heat and are therefore a tool for temperature management. The first temperature management goal when using high tunnels is to protect the fruit and flowers from frost injury. This means keeping the temperature above 28˚F when there are fruit or flowers on the plant. The second goal is to keep temperatures 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°F. 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 as close to the optimal range (70-80°F) as possible. For more information on managing tunnel temperatures see the linked USU Extension fact sheet.

Low tunnels (Figure 3) installed over individual rows provide an additional 1-3°F of nighttime protection. If using low tunnels, the most critical time is protecting the developing flowers and fruit in the fall harvest window. However, there also may be some benefit in the spring to accelerate plant establishment. For more information on constructing and managing low tunnels see the USU Extension low tunnel fact sheet. Use caution 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, high tunnels alone can be expected to yield a 30 degree temperature lift over outside conditions on a sunny day. When low tunnels are used in conjunction with high tunnels, another 5-10 degree day-time temperature lift within the low tunnel is usually realized.

Ventilation

High tunnels warm very quickly under sunny conditions, even when outside temperatures are low. Figure 4 shows tunnel temperatures over two sunny winter days when outside daytime temperatures were in the 30s. Note that the mid-day temperatures were in the 60s. Low tunnels added an additional 2-5˚F. Keep a thermometer in the tunnel at the height of the plants to accurately determine ventilation needs. Remember, tunnels should be managed to try to maintain plant temperatures as near 70-80°F as possible. Some days may require the high tunnels be vented with just small endwall vents. Warmer days may need the main door open. Late in the spring and early in the fall, high tunnel sidewalls can be lifted for cross ventilation to achieve significant cooling.

Summer Care

High tunnel plastic can be removed once all risk of spring freezes has passed. Applying a 30% shade cloth during the summer will provide cooling during a time when temperatures are typically super-optimal for strawberry growth. Shade application directly over the tunnel structure (Figure 5) worked well in our trials and reduced air temperature by up to 15°F. Remove shade cloth and replace with high tunnel plastic once outdoor temperatures begin to decrease. Runners should be removed weekly. Runner production will significantly decrease once fruit development begins.

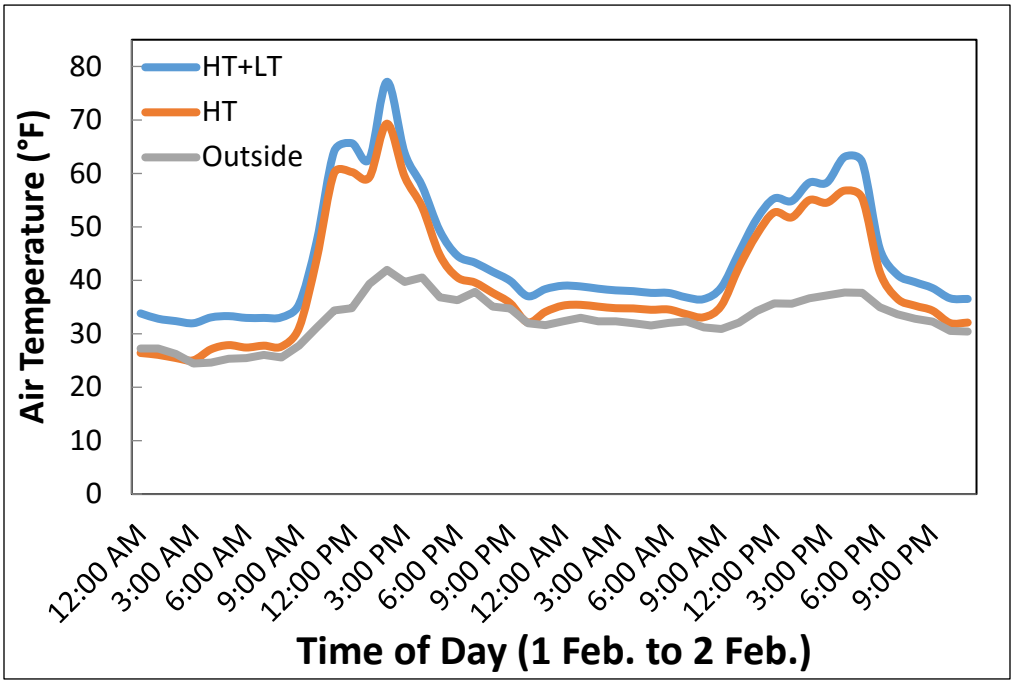

Figure 4. Air temperature outside and inside high (HT) and low tunnels (LT) over 2 late winter days.

Figure 5. Shade cloth applied over high tunnel structure.

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. Conduct a routine soil test to determine any soil nutrient needs prior to planting. This is important for planting in new locations, or areas that have not been soil tested in the last one to two years. USU's Analytical Laboratories performs soil tests. Pricing and information for collecting a sample is available on their website.

Table 1. Fertilizer program for high tunnel strawberries on loam soil in North Logan, Utah.

Growth stage	Fertilizer (NPK)	Application Rate (ppmN)	Mixing Instructions
Vegetative	20-20-20	100	¾ tsp fert/10 gal
Flowering	10-20-10	50	1/3 tsp fert/10 gal
Harvest	10-30-10	25	1/5 tsp fert/10 gal

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 fertilizer regime detailed in Table 1 to be effective. When selecting a fertilizer source, consult your vendor to be sure the selected mix can be readily dissolved in water to avoid problems with the injector or plugging 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.

Pests

Grey mold (Figure 6) is a fungal pathogen that thrives in warm humid environments (common in high tunnels). Airflow from ventilation and care to avoid introducing too much water into the high tunnel system helps minimize occurrence. The infection typically occurs during bloom, then remains latent until the fruit begin to ripen. Infection of the fruit can be avoided by minimizing irrigation water splashing onto the blossoms, which is facilitated by using drip irrigation placed below the plastic mulch. Good sanitation practices (removing diseased or dead plant tissue from the tunnel) also reduces disease pressure. Timely applications of a fungicide such as Captan may also be required.

Figure 6. Grey mold on strawberry

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. Reference our high tunnel IPM fact sheet for more information about high tunnel pest management.

Table 2. Monthly timeline for spring-planted, late-summer and fall harvested high tunnel strawberries.

October	February-May	June	July-August	September	October-November
Prep beds and high tunnel for planting.	Plant dormant plants. Plant establishment. Tunnel Ventilation.	Remove tunnel plastic. Install shade cloth. Early Summer harvest.	Remove runners. Late Summer harvest.	Remove shade cloth. Install Plastic.	Fall Harvest.

Research Results

Cultivar Comparison:
Four day-neutral cultivars (Albion, Evie 2, Seascape, and Tribute) were compared for high tunnel production. Table 3 compares several characteristics among these cultivars. Yields were compared for summer (20 May to 12 Aug), early fall (13 Aug to 12 Oct), and late fall production (13-Oct to 15 Dec) windows (Table 4). 'Evie 2' was determined to be most suitable for high tunnel production based on higher yields, more uniform seasonal production and larger berry size than other evaluated cultivars. 'Evie 2' also showed more tolerance to extreme summer heat. 'Seascape' was considered to be the second best option with good yields, good fruit size and greater resistance to grey mold than 'Evie 2'

High Tunnel
High tunnels provided more hours of optimal growing conditions per day in the early spring and late fall than the field planting. This resulted in spring production being advanced by 3 to 4 weeks compared to spring field-planted day-neutral cultivars. Fall harvest continued through November, although late fall yields were fairly low Ttable 4). In addition to extending the harvest season, total plant yields in the high tunnel system were significantly greater than plants in the field (Figure 7). In 2008 and 2009, high tunnel plants averaged 1.6 and 0.4 pounds per plant more (respectively) than plants in the field (Figure 7). The more pronounced high tunnel benefit in 2008 was due to a colder spring than 2009 where the first field flowers were repeatedly lost to freeze events and the fruit that developed from the remaining flowers was below marketable size.

Low Tunnel
Low tunnels constructed within the high tunnels were effective at further increasing the number of hours of optimal growing conditions above the high tunnel alone. However, yield increases were inconsistent (Figure 7). Proper management of low tunnels is labor intensive (frequent ventilation) and increases material costs. The use of low tunnels may not be economically viable in all situations.

Economics
Harvested fruit was sold at both farmers markets and USU campus stores to evaluate the profitability of locally-grown, late-season strawberries. Reference table 5 for a detailed enterprise budget. Prices are from the Logan, Utah market and should be adjusted to match individual operation costs and sales. The net income of one 14 x 96' high tunnel was $741 or $14,820 per acre assuming 20 tunnels.

Conclusion
High tunnels are an intensive system that require careful planning and daily monitoring. With proper management and care, high tunnels have proven effective at advancing and extending the harvest season of spring-planted, day neutral strawberries. Low tunnels inside a high tunnel provide additional protection from freezing temperatures but may not increase total yield and require additional labor input.
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Table 3. Comparison of 4 day-neutral strawberry cultivars tested for Utah high tunnels.

Cultivar	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

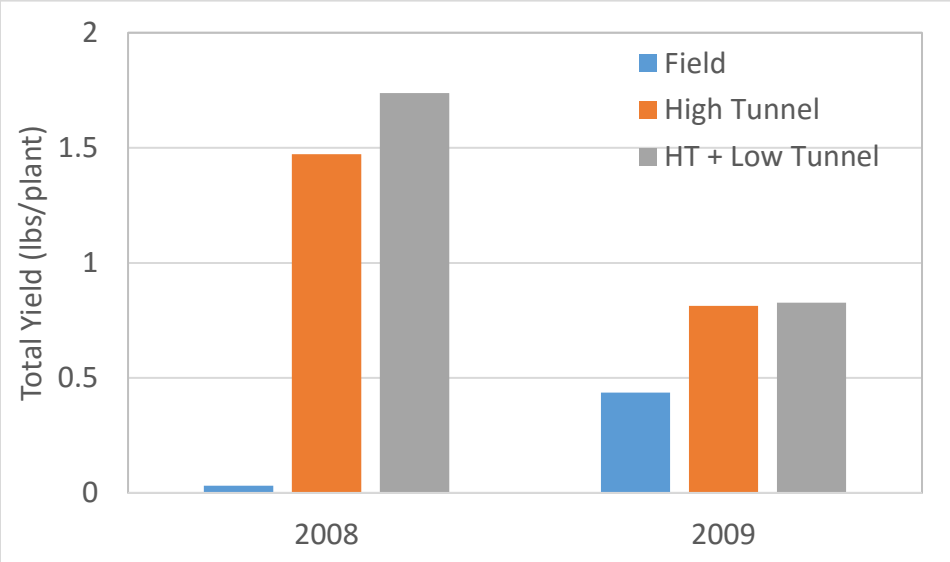

Figure 7. Total yield compared between field*, high tunnel and high tunnel + low tunnel systems. *Evie 2 only

Table 4. Yield comparison among four varieties grown in a high tunnel. Yield is divided into three production periods: summer (20 May to 12 Aug), early fall (13 Aug to 12 Oct) and late fall (13Oct to 15 Dec).

	2008 Yield (lbs/plant)			
Cultivar	Summer	Early Fall	Late Fall	Total
Albion	0.34	0.44	0.38	1.17
Evie 2	0.87	0.70	0.31	1.89
Seascape	0.77	0.53	0.54	1.84
Tribute	0.62	0.54	0.36	1.53

Additional Reading

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USDA U.S. Department of Agriculture Risk Management Agency

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Table 5. Spring-plant, high tunnel strawberry enterprise budget for a 14' x 96' tunnel.

		1- 96 ft tunnel		
Revenues	Units	Quantity	Unit Price	Total
In-Season Strawberries (Jun-Sept)	1 lb	748	$4.50	$3,366.00
Late Out-of-Season Strawberries (Oct-Now)	1 lb	134	$6.00	$ 804.00
Total Revenues				**$4,170.00**
Operating Expenses				
Supplies				
Preplant and preparation costs				
Soil test	Each	1	$25.00	$ 25.00
Fuel	Gal	0.38	$3.50	$ 1.31
Preplant fertilizers and amendments	Lbs	2.25	$15.00	$ 33.75
Plastic mulch	Ft	281	$0.05	$ 14.06
Drip tape	Ft	576	$0.05	$ 28.80
Strawberry establishment and growth				
Plug plants	Each	563	$0.10	$ 56.30
20-20-20 water soluable fertilizer mix	Lbs	19	$1.23	$ 23.52
10-30-20 water soluable fertilizer mix	Lbs	6	$1.49	$ 9.39
Captan	Lbs	0.84	$9.82	$ 8.29
Thionex 50 W	Lbs	0.06	$7.51	$ 0.42
Strawberry harvest				
1 lb clamshells	Each	884	$0.25	$ 221.00
Total Supplies				**$ 421.84**
Labor				
Preplant and preperation costs				
Soil test	Hours	0.5	$13.50	$ 6.75
Apply preplant fertilizers	Hours	0.75	$13.50	$ 10.13
Tillage	Hours	7.5	$13.50	$ 101.25
Form raised beds	Hours	13	$13.50	$ 175.50
Install drip tape	Hours	0.75	$13.50	$ 10.12
Cover with plastic mulch	Hours	1	$13.50	$ 13.50
Strawberry establishment and growth				
Planting labor	Hours	6	$13.50	$ 81.00
Fertigation	Hours	2	$13.50	$ 27.00
Pesticide applications	Hours	9	$13.50	$ 121.50
Hand weeding	Hours	6	$13.50	$ 81.00
Plastic and shade cloth install/removal	Hours	12	$13.50	$ 162.00
Monitoring and ventilation	Hours	30	$13.50	$ 405.00
Strawberry harvest				
Hand harvest	Hours	107	$13.50	$1,444.50
Post-harvest				
House clean out	Hours	4.5	$13.50	$ 60.75
Total Labor				**$2,700.00**
Total Operating Expenses (supplies & labor)				**$3,121.84**
Fixed Expenses (Depreciation)				
High Tunnel Annual*				$ 248.17
Irrigation System Annual*				$ 58.82
Total Fixed Expenses				**$306.99**
Total Expenses				**$3,428.83**
Net Income				**$ 741.17**

* Detailed fixed expenses breakdown available here.