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High Tunnel Strawberry Production for Early Spring 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 frequent spring freeze events during flowering often limit production. 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 a fall-planted, spring-harvested system. A spring-planted, fall-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, resulting in earlier 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.

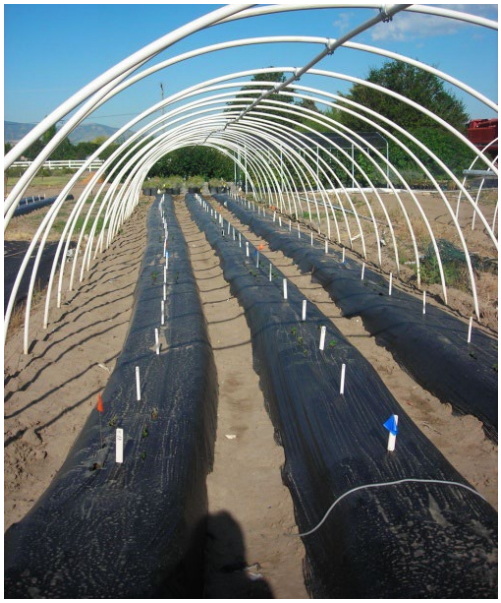

Figure 1. Raised beds, ready for planting annual strawberries. Beds are 8-10 inches tall, 24 inches wide and covered with plastic mulch. Note plastic is not yet installed over tunnel.

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 a concentrated spring-harvest, either June-bearing or day-neutral strawberries can be used. However, we found better performance with June-bearers.

Plant Type

Plug plants or dormant plants can be used for fall planting (Figure 2). Plugs are actively growing rooted plants. They can be difficult to source in late summer, but are relatively easy to produce on your own. The USU Extension fact, Propagating Strawberry Plugs provides a step-by-step guide for production. Bare-root dormant plants are dug in the late fall or winter and then cold stored until planting time. They are also difficult to obtain in late summer. However, some nurseries will hold dormant stock for late summer plantings if ordered well in advance. You can also order dormant plants for spring delivery and store in refrigeration until planting. However, extended storage requires the proper temperature and humidity and plants can easily become too dry or wet resulting in plant loss. Plug plants are recommended over dormant plant material. In our trials, dormant plants had a much lower survival rate in the high tunnel and field than plug plants (53% dormant, 87% plug) and required more runner removal. Additionally, fruit harvest from dormant plants was 7 to 19 days later than from plugs.

Figure 2. Actively growing rooted plug plant (left) and bare-root dormant plant (right).

Planting Date

Fall planting needs to be timed correctly as planting too early results in excessive runner formation (unwanted growth in an annual hill system) and planting too late does not allow enough time for plants to develop adequate branch crowns. Optimum plant establishment produces about 4 to 5 branch crowns per plant by the start of the harvest season. For plug plants, the ideal planting date for high tunnels in North Logan, UT (elevation 4692, latitude 41.735 N), is the first week of September (Figure 3). This optimized planting date resulted in minimal fall runnering, 4 to 5 branch crowns per plant, and high total yields. This date should be adjusted depending on your location. Earlier planting dates will be needed in higher elevation and more northern locations. Dormant plants need more time to establish and form sufficient crowns. Optimum planting dates for dormant plants in North Logan was the end of July. When deciding on planting type, consider the additional time dormant plants will occupy the tunnel, and the increased labor costs of tunnel management, irrigation, and runner removal.

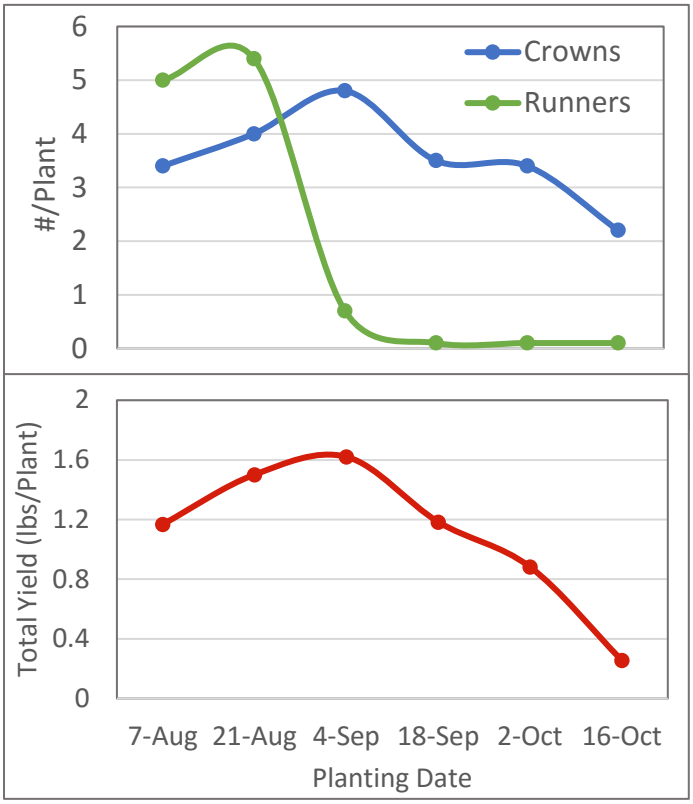

Figure 3. The effect of planting date on fall runners, spring crown number, and total spring yields for plug plants in North Logan, Utah (4692 ft elevation, 41.735 N. latitude). Optimum planting date is typically the first week of September, based on maximum crown number, total yields, and minimum fall runners.

Establishment and Fall Care

It is important to keep the soil moist during establishment. Under our soil and weather conditions, this required about two irrigations per week. It is not critical to have the plastic installed on the high tunnel at planting, especially if using dormant plants. Install plastic once nighttime lows are consistently below 50°F. Be sure to have plastic in place before the first heavy fall rain or snowstorms, as putting on plastic after will trap excess moisture inside the tunnel and is difficult to dry out once temperatures drop. Excessive moisture can lead to increased disease incidence. Depending on cultivar, plant type and planting date, the plants may begin to send out runners that should be removed at least weekly. Dormant plants produce more runners than plug plants.

Winter Care

Growth will slow as temperatures decrease. However, some growth will continue into the winter, which will require periodic runner removal. Removing runners at about 2 to 3 week intervals during December and January was sufficient in North Logan tunnels. Winter and early spring irrigation in a Utah high tunnel is typically from a culinary water source, as secondary irrigation options are not available. Freeze-free faucets are critical, and hoses should be drained after each use to avoid freezing. Fortunately, very little water is needed during this time, but it is best to monitor soil moisture levels to ensure the soil does not become too dry. 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 4) for PVC-frame tunnels to prevent the collapse until the snow can be swept off.

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 in the early and late parts of the year. This means keeping the temperature above 28˚F, especially 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 within or as close as possible to the optimal range (70-80°F). For more information on managing the tunnel temperatures to optimize crop growth see the linked USU Extension fact sheet.

Figure 4. Low tunnels over raised beds inside a high tunnel. Snow supports are the wooden 2x4s in the middle row.

Low tunnels (Figure 4) installed over individual rows provide an additional 1-3°F of nighttime protection. If using low tunnels, install them in late fall or early winter and they can be removed after the risk of spring freezes are past. 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 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 5 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 only require the high tunnels be vented with just small endwall vents. Warmer days may need the main door open. Late in the spring, high tunnel sidewalls can be lifted for cross ventilation to achieve significant cooling.

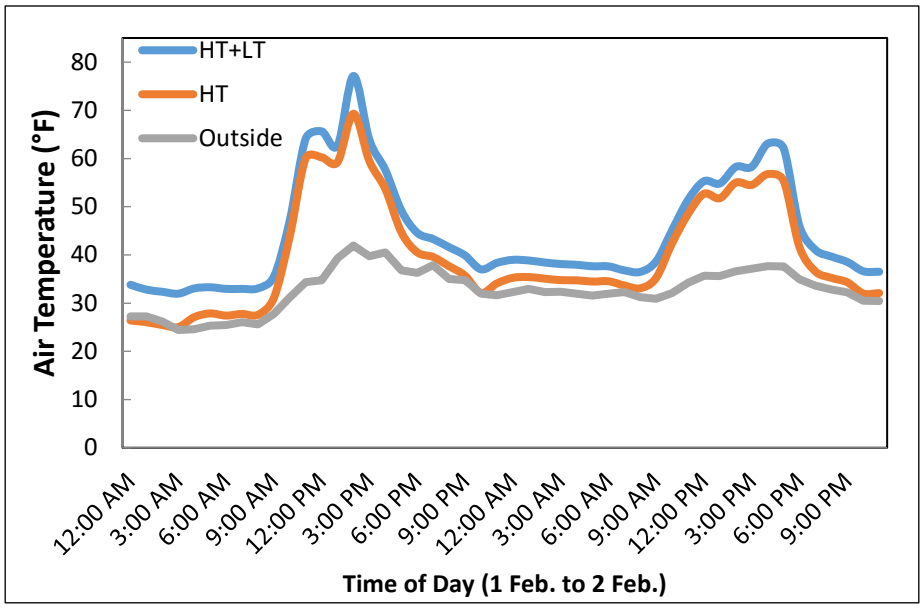

Figure 5. Air temperature outside and inside high (HT) and low tunnels (LT) over 2 winter days.

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 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.

Table 1. Fertilizer program for high tunnel strawberries.

Growth stage	Fertilizer (NPK)	Application Rate (ppm N)	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

Pests

Grey mold (Figure 6) is a fungal pathogen that thrives in warm humid environment (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, good sanitation practices (removing diseased or dead plant tissue from the tunnel), and with timely applications of a fungicide such as Captan.

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.

Figure 6. Grey mold on strawberry

Research Results

When compared with unprotected, field grown strawberries, high tunnels increased total yield by an average of 1.3 pounds per plant in 2012 (Figure 7). This large increase was seen for both the June-bearing ('Chandler') and the day-neutral ('Seascape') cultivars. Throughout our trials, June-bearing, plug plants consistently had the highest plant survival and yield. In a comparison study, low tunnels were installed over beds without high tunnel protection (Figure 8). Low tunnels on their own were not effective at protecting strawberry blossoms and did not increase yield compared to unprotected plants (Figure 7).

Over our 5 years of research, high tunnel grown plants consistently began production about 4 weeks earlier than field grown plants. Example harvest start dates (2012) are shown in Table 3. There was no significant difference in total yield between high tunnels alone and high tunnel plus low tunnels (Figure 7). This may vary depending on spring temperatures. The year of this study (2012), spring freezes were few and not severe. In a spring with more freeze events, low tunnels may have a larger effect. Although total yield was not increased with low tunnels, the additional heat accumulation moved production forward by an additional 2 weeks (Table 3), a significant benefit for early spring markets.

Economics

Harvested fruit was sold at both farmers markets and USU campus stores to evaluate the profitability of locally-grown, early season strawberries. Early season fruit quickly sold out at $6.00 per pound in these markets. The price was reduced to $4.50 per pound once field-grown plants began producing. The net income of one 14 x 96' high tunnel was $1,944, or $38,885 per acre assuming 20 tunnels. For detailed budget information reference USU's companion enterprise budget. Additionally, a partial budget evaluating the economic effect of using low tunnels inside a high tunnel is available.

Table 2. Monthly timeline for Spring-harvested, high tunnel strawberries.

June-July	August	September	October	Nov-April	May-June
Plug plant production	Harden off plug plants. Prep beds and high tunnel for planting.	Plant plug plants. Plant establishment.	Continue plant establishment and remove runners. Install tunnel plastic.	Remove runners, irrigate and manage temperature as needed.	Harvest

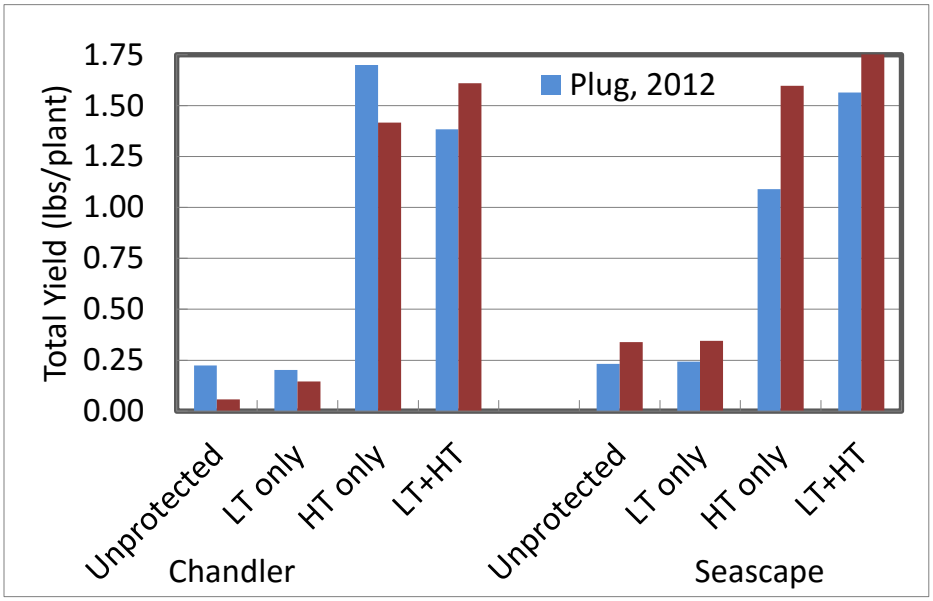

Figure 7. Total yield of two cultivars ('Chandler' and 'Seascape') compared among unprotected (field) plants, low tunnel (LT) only, high tunnel (HT) only, and low tunnel + high tunnel. Two plant types, plug and dormant, were also compared.

Figure 8. Low tunnels over strawberry beds without high tunnel protection.

Table 3. First commercial harvest date compared among unprotected, low tunnel only, high tunnel only and low tunnel + high tunnel 'Seascape' plants.

	Plug 1st Harvest	Dormant 1st harvest
Unprotected	21-May	31-May
LT Only	21-May	31-May
HT Only	20-Apr	1-May
HT+LT	10-Apr	17-Apr

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 expanding the harvest season for strawberries. Low tunnels inside a high tunnel further advance the season but may not increase total yield. Further options of season extension using minimal in-ground heating were explored and research results are available on tunnel.usu.edu.

Additional Reading

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USDA U.S. Department of Agriculture Risk Management Agency

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