Growing Strawberries in High Tunnels in Missouri

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Figure 1. High tunnel strawberry production research in Columbia, MO, 2006

Introduction

Strawberries are one of the most popular fruit crops produced in Missouri. The typical field production season for this high-value crop is mid- to late May through June for matted row (open field) berries. High tunnels may give growers the opportunity to produce early-season or late-season strawberries in Missouri. High tunnels are unheated, plastic-covered, solar greenhouses. Ventilation is passive through roll-up side walls or curtains and roof vents. Crops are grown in native, mineral soil under the high tunnel. The high tunnel protects the growing crop from environmental extremes such as wind, hail, rainfall, insects and diseases which allows for significantly earlier and higher marketable yields. Since high tunnels have low startup and operating costs, a single crop often provides enough revenue to pay for the cost of the structure.

Strawberry Culture

In 2006, I initiated a high tunnel strawberry evaluation using 'Chandler' variety. 'Chandler' is a productive, plasticulture strawberry variety which performs well even as a field variety in southern Missouri (Zone 5B and 6). 'Chandler' is relatively susceptible to anthracnose, a fungal disease often triggered by rainfall.

Using plug plants obtained from Jersey Asparagus Farms, Inc. (see appendix), the strawberries were planted in mid-September 2005 in each of four high tunnels (20 ft wide x 12 ft high x 36 ft long) in Columbia, MO. Each high tunnel had a single layer of 6-mil plastic.

Rooted, plug plants are more expensive than using dormant runner tips, but good quality plants with strong root systems are quick to get established. Dormant runner tips can be purchased from many northern nurseries and rooted in 50-cell trays. Tips should be rooted in late August since it will take approximately 4 weeks to develop a root system. To accelerate root growth, the runners stubs can be dipped in a rooting powder (e.g., Rootone®) (Figure 2). Try to root runner tips as soon as they arrive.

Figure 2. Strawberry runner tips should be rooted approximately 30 days before transplanting in a high tunnel.

Each runner tip can be rooted using standard potting mix and 50-cell planting trays. If there is variability in size of the runner tips, the larger tips can be rooted in a 38-cell tray. After planting in trays, the plantlets can be placed in a greenhouse under a mist bed. Some growers have had success rooting strawberry runner tips by placing the trays on a wagon in indirect sun and watering twice daily.

A. Fertilizer and Soil Fertility

A soil analysis should be performed prior to planting strawberries within a high tunnel. The optimal pH range for strawberries is 5.8-6.5. Preplant, granular fertilizer (10N-10P-10K) can be broadcast over each raised bed prior to laying plastic mulch. Approximately 30-40 lbs (per acre equivalent) of nitrogen is sufficient for strawberries which is 0.7-0.9 lbs of actual nitrogen/1000 ft^2 of bed area. Generally speaking, a granular fertilizer (such as 13-13-13) broadcast over the beds before planting is best, but if you choose to not apply fertilizer this way, you can apply a soluble fertilizer (such as 20N-20P-20K) through the drip irrigation system. It's very important not to apply too much preplant nitrogen to strawberries (especially 'Chandler'). Also, if a lot of manure or compost has been applied to the soil within the high tunnel, no preplant nitrogen will be needed. Excessive nitrogen will result in an abundance of branch crowns. When a strawberry plant has too many branch crowns, the average fruit size is significantly reduced.

When the strawberries emerge from dormancy the following spring and resume growth, additional nitrogen (approximately 5 lbs/acre/week equivalent of <u>*actual*</u> nitrogen or 1.8 ounces of <u>*actual*</u> nitrogen/1000 ft^2/week) can be applied via the drip system. At first flowering, a tissue test should be performed by taking a few leaf samples from each high tunnel, drying them, and sending them to a diagnostic lab for analysis. Always choose a recently mature leaf from a single variety. Generally 20 leaves per high tunnel per variety will be sufficient. Consult your local extension agent for details about sufficiency ranges for tissue tests.

Strawberries are especially sensitive to salt in the soil. Have the soil tested for soluble salts. Soil salinity can be a problem if a lot of high salt fertilizers or animal manures are used over time. Normally rainfall would leach these salts out of the root zone, but since the high tunnel excludes rainfall, salts will accumulate. Salts within the soil make it harder for the plants to extract water from the soil (Upson, 2006)

In the high tunnel, strawberries can be rotated with such crops as tomatoes or peppers. It is true that both tomatoes and strawberries can share certain soilborne diseases (*Verticilllium* wilt). However, as long as you don't have a disease outbreak, rotation is flexible within the high tunnel.

B. Spacing and Planting

Each plant was planted 12 inches apart within the row with rows spaced 12-15 inches apart. Each row was offset from the other so as to produce a staggered planting arrangement (Figure 3). All planting within the high tunnel was done by hand. After planting, apply a starter solution (for example, 9N-45P-15K fertilizer) to encourage root growth. One of the keys to success with high tunnel strawberries is obtaining an optimal plant population. A four-row bed with each plant spaced 12-15 inches apart is an optional planting arrangement for high tunnels (Figure 2). In a commercial high tunnel (2500-3000 ft^2), approximately 1200-2000 strawberry plants can be planted using the twin to four row planting arrangement.

C. Drip Irrigation

When there are 2 or more rows per bed within a high tunnel, 2-3 drip lines are essential for uniform watering. This is particularly true with coarse or sandy soils. Each drip line can be placed between each row on the bed. Choose drip lines with a 4-6 inch dripper spacing, and bury the drip line about 1-2 inches in the bed with the drippers (emitters) facing upward. Burying the

drip tape protects it from rodents and prevents movement of the drip line in hot or cold temperatures. If Queen Gil® drip tape is used, it must be buried to properly distribute water. In early fall after transplanting, irrigate approximately 3-4 hours per week. When the weather gets cool, and the plants are transpiring less, irrigation frequency can be scaled back. No irrigation will be necessary during the winter months when the strawberries are dormant. Irrigation can be scheduled using either an irrometer (tensiometer) or the "feel" method. If an irrometer is used, the reading should be in the 20-30 cb range at the 12" depth. For details on using the "feel' method, consult the *Midwest Vegetable Production Guide* (Table 8).
It is essential not to over water strawberries since they do not thrive in waterlogged soils.

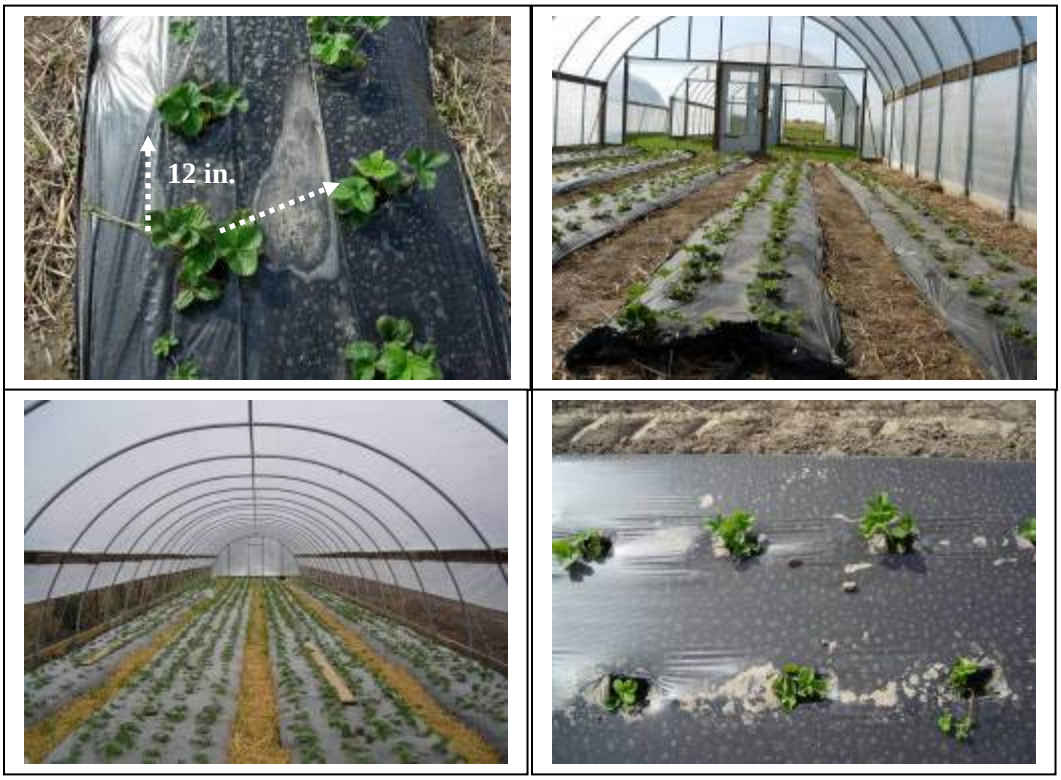
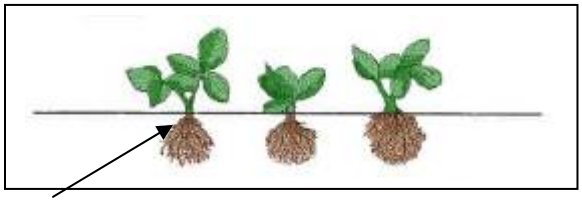
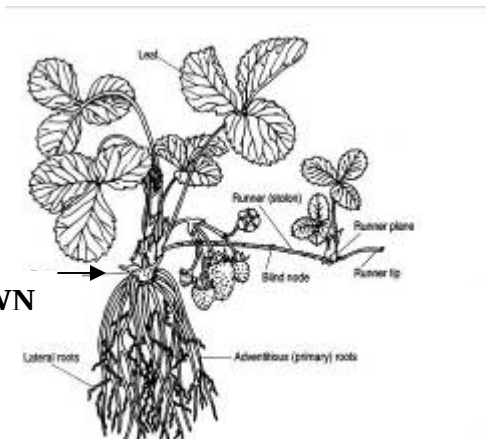


Figure 3. Strawberries are planted on raised beds with 2 rows or 4 rows per bed. Each plant should be planted in an alternate planting arrangement for maximum light interception.

Do not plant the strawberries too deep. I usually plant about midway up the crown, making sure not to bury the crown (Figure 4). Strawberries should be planted within a high tunnel from mid-September until mid-October in Central Missouri. Planting too late will result in less branch crowns per plant, poor winter hardiness, and the plant may produce an abundance of runners the following spring.



Proper planting depth
Figure 4. Planting depth for strawberries.



Anatomy of a strawberry plant.

D. Row covers

As the strawberries continue to grow in the fall, the crown grows producing 4-5 branch crowns per plant. Each branch crown will produce about 10 flowers. These flower trusses directly translate into marketable yield. However, it is important not to get too many branch crowns since this will result in a lot of small fruit. Too many branch crowns could be formed if the row covers are placed on the strawberries too early. Remove any runners or flowers which appear in the fall. This channels energy into branch crown formation.

Figure 5. Row covers are used on strawberries for frost or freeze protection.

Row covers are lightweight blankets of spun bonded fabric which are placed over plants to protect them from frost or freezes (Figure 5). Row covers (1 oz/yard^2) provide 4-6°F protection in the open field and nearly double that when used within a high tunnel. Using row covers on strawberries is tricky. Extended use of row covers could cause the strawberries to bloom too early resulting in lost yield. However, failure to use a row cover may result in freeze damage to the crowns. If the winter season *is mild*, I would use row covers in a high tunnel only for freeze protection (temperatures lower than 20°F) and frost protection (temperatures lower than 34°F) for the blooms the following spring. If the winter season temperature *is average to below average*, I would apply a medium weight row cover (1 oz/yd^2) in late December and keep it on the plants until they begin sprouting new leaves from the crown in February. Taking the row covers off at the beginning of leaf growth will slow the plants down so they don't flower too early. Flowering should commence in early to mid March on 'Chandler' within a high tunnel in Missouri in order to begin harvesting in early April. Remember, strawberries are a cool season crop, and the high tunnels should be kept relatively cool during the winter. Therefore, some venting may be necessary during mild winter days. If temperatures get too warm within the high tunnel, the strawberries may flower too early resulting in lost yield.
When the 'Chandler' strawberries are beginning to go into dormancy in late December, they should have approximately 8 leaves per plant.

E. Pollination and Fruit Set

The 'Chandler' strawberries began to bloom in mid-March in Columbia, MO. At that time, the vents were closed most days, and many natural pollinators could not enter the high tunnel. Strawberries will set fruit without pollinators, but maximum berry size and weight are obtained by having good cross pollination of flowers with bees (Figure 6A).

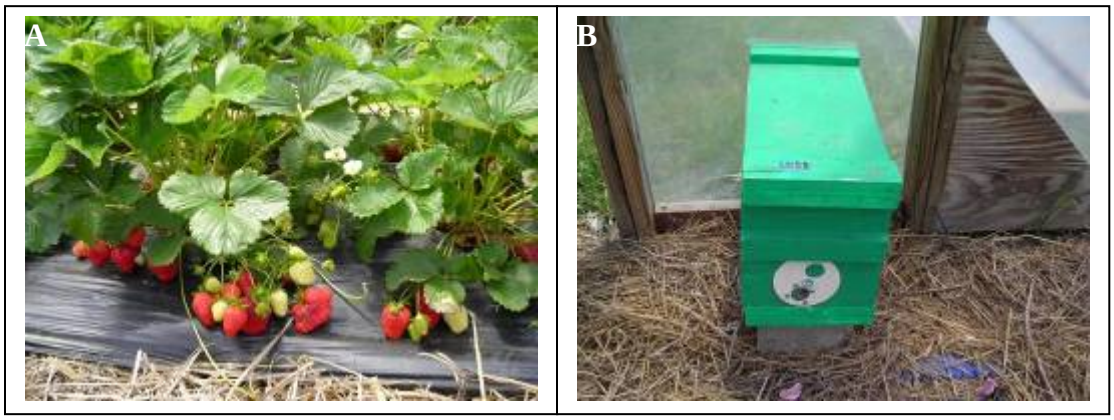


Figure 6. A. Effective pollination of strawberries is essential for maximum yield. **B.** A NUC box used for honeybees within a high tunnel (Courtesy: Jann Amos).

Different pollinators for high tunnel strawberries were evaluated in 2006 using honeybees, bumblebees and natural pollinators (flies, solitary bees, wasps and native bumblebees). For honeybees, a small NUC colony that was placed in one of the high tunnels (Figure 6B). An entry/exit hole was made so the bees could freely exit the high tunnel from the 3-frame NUC box. A Class C "mini hive" of bumblebees containing about 200 bees was used to evaluate bumblebee pollination (Hydro-Gardens Inc.). Class C hives will last about 5 weeks. One high tunnel was used to evaluate natural pollinators. Any pollinator which entered the high tunnel from the outside was considered a natural pollinator.

Honeybees were the most effective pollinators as measured by a significant increase in marketable berry weight, but the bumblebees were close behind (Figure 7). There was no difference in earliness with either bee treatment, although the naturally-pollinated high tunnel was harvested one week later. Generally speaking, honeybees were easy to manage within the high tunnel. They seemed disoriented at times, but were not a management problem. However, if the high tunnel is used for strawberries and other vegetables concurrently, the bees may interfere with planting and other activities. Honeybees will seldom fly at temperatures less than 55°F. Fortunately during March, the high tunnels are warm and the bees are active. Bumblebees are active in cooler weather and are more controlled in their flying behavior within a high tunnel. They are very efficient pollinators working the flowers until dark. However, since there are fewer bumblebees relative to honeybees, they must be prevented from leaving the high tunnel through vents and other openings. Insect screening can be placed over the sidewalls to prevent the bumblebees from escaping the high tunnel. Insect screening will also prevent aphids and mites from colonizing most high tunnel crops.

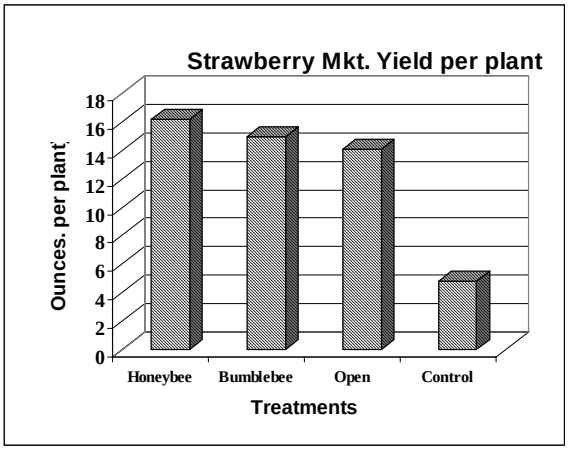


Figure 7. Evaluation of pollinators for high tunnel strawberry production. Control was open-field 'Chandler' planting.

F. Pest Management

One of the most serious diseases of high tunnel strawberries is *Botrytis* gray mold. Gray mold is severe in cloudy, cool, humid conditions. Gray mold is a fluffy fungal growth on the fruit or flower stalks making the fruit unmarketable (Figure 8A). Avoid high humidity within the high tunnel. Excessive foliage from too much nitrogen fertilization can also trigger gray mold problems. Beginning at flowering the blooms can be sprayed with a fungicide such as Topsin®, Captan®, Thiram® or Pristine®.

Figure 8. *Botrytis* gray mold (A) and spider mites (B) on strawberries can be a problem in high tunnels.

Aphids can develop within the high tunnel especially if the plants are over fertilized with nitrogen. Spider mites will often develop as a problem in May. Damage from spider mites looks a lot like a nitrogen deficiency (yellowing of leaves)(Figure 8B). Predatory mites can be used to control spider mites if they are detected early enough. Otherwise, there are several registered miticides which will effectively control this pest. Consult the *Midwest Small Fruit Management Handbook* for more information on pests affecting strawberries.

G. Harvest

Most strawberries were harvested starting 28 days after flowering. Harvest commenced on April 12, 2006 which is at least 4 weeks earlier than field-grown, matted row strawberries and 2 weeks earlier than plasticulture, open-field 'Chandler' strawberries. Over 95% of high tunnel picked berries were marketable, relative to only 60% for an open field plot of 'Chandler' berries. Size and quality were excellent with most berries averaging approximately 12% sugars. 'Chandler' berries are firm with good shelf life. The berries were harvested in pulp, quart baskets and test marketed in early May at three wholesale produce auctions in Missouri (Figure 9). Prices ranged from $2.75- $6.00/quart with an average price of $4.40 per quart ($3.67/lb.). As supplies of local berries increased, the price expectedly declined significantly. However, high tunnel strawberries peaked in yield before local supplies became significant. Harvest continued until June 10, 2006. In late May, a shade cloth was placed on the high tunnels to lower temperature within the high tunnel.

Figure 9. Strawberries can be packed in a variety of containers for sale.

The use of a shade cloth seemed to improve fruit quality as temperatures increased. Average marketable yield across all high tunnels was 1.2 lbs (1 quart) of berries per plant. In order for high tunnel strawberries to be profitable, each plant must yield at least 1 pound of marketable fruit. High tunnels seem to offer potential for Missouri growers to expand their production and marketing season for strawberries.

I. Economic Analysis

Table 1. High Tunnel Strawberry Enterprise Budget (650 strawberry plants per 1000 ft^2).

Production Expense	Unit	Quantity	Price	Labor (rate/h)	Hours	Total Costs ($)
Variable Costs:						
Pre-planting						
Soil test			4.00	8.0	0.5	**8.00**
Tillage			5.00	8.0	0.5	**9.00**
Raised bed formation				8.0	3.0	**24.00**
Fertilizer and Lime		1.1 lbs N	17.64	8.0	0.5	**21.64**
Plastic mulch (5 rows)		158 linear ft.	6.08	8.0	1.5	**18.08**
Irrigation drip tape		411 ft.	11.78	8.0	0.5	**15.78**
Plant Costs:						
Plants[z]	Plugs	650	130.00			**130.00**
(Plants)	Runner tips	650	65.00			**(65.00)**
(Rooting media)	3.8 ft^3	1 bale	14.78	8.0	0.5	**(18.78)**
(Planting trays)	50-cell	13	12.35	8.0	1.5	**(24.35)**
Planting				8.0	4.0	**32.00**
Starter fertilizer	9-45-15	1 lb	2.50			**2.50**
Production Costs:						
Insecticide/Miticide			1.75	8.0	1.0	**9.75**
Fungicide			5.22	8.0	1.0	**13.22**
Irrigation/Fertigation			6.35	8.0	5.0	**46.35**
Tissue samples		1	5.67	8.0	0.5	**9.67**
Row covers			39.67	8.0	0.5	**47.67**
Anchor pins			9.98			**9.98**
Fuel and oil			2.50			**2.50**
Pollination			21.67			**21.67**
Temp. mgt.	**Complete high tunnel**			8.0	5.0	**40.00**
Harvesting Costs:						
Picking				8.0	12	**96.00**
Postharvest Costs:						
Boxes	Quart	542	0.12			**65.00**
Carriers	Box/tray	68	1.00			**68.00**
Marketing Costs:						
Delivery				8.0	6	**48.00**
Total Production Costs						**738.81**
						(716.94)[y]
Total Fixed Costs						**100.16**[x]
Total Costs per 1000 ft^2						**838.97**
						(817.10)

[z]Does not include freight costs for either plugs or runner tips.
[y]Total production costs using rooted, runner tips.
[x]Total fixed costs calculated based on using the high tunnel for 1/3 of the calendar year for strawberries.

High tunnel strawberries are ready for market in early April when local berry supplies are low and imported berries have inferior taste and appearance. The break even price for high tunnel strawberries was calculated to be $1.28/lb or $1.53 per quart assuming an average yield of 1 lb per plant. Most growers should expect a retail price of at least $3.00/lb or $3.60 per quart. Wholesale prices should exceed $2.50/lb or $3.00/quart (Table 2). After the strawberries are harvested in mid June, they can be followed by such crops as tomatoes, peppers, melons, cucumbers or squash.

Table 2. Net returns ($) per 1000 ft^2 (650 strawberry plants).

Price per lb ($)	Yield per plant (lbs)[z]			
2.00	**0.75**	**1**	**1.25**	**1.5**
2.25	136.03	461.03	786.03	1111.03
2.50	257.91	623.53	989.16	1354.78
2.75	379.78	786.03	1192.28	1598.53
3.00	**501.66**	**948.53**	**1395.41**	**1842.28**
3.25	623.53	1111.03	1598.53	2086.03
3.50	745.41	1273.53	1801.66	2329.78
3.75	867.28	1436.03	2004.78	2573.53
4.00	989.16	1598.53	2207.91	2817.28
4.25	1111.03	1761.03	2411.03	3061.03
4.50	1232.91	1923.53	2614.16	3304.78
4.75	1354.78	2086.03	2817.28	3548.53
5.00	1476.66	2248.53	3020.41	3792.28
5.25	1598.53	2411.03	3223.53	4036.03
5.50	1720.41	2573.53	3426.66	4279.78
5.75	1842.28	2736.03	3629.78	4523.53
6.00	1964.16	2898.53	3832.91	4767.28

[z]One quart of strawberries equals 1.2 lbs.

Useful References

Midwest Strawberry Production Guide. 2006. The Ohio State University Bulletin 926.

Midwest Vegetable Production Guide for Commercial Growers. 2007. University of Missouri Extension Publication MX 384.

Midwest Small Fruit Pest Management Handbook. 2006. The Ohio State University Bulletin 861.

Midwest Commercial Small Fruit Spray Guide. 2007. University of Missouri Extension Publication MX 377.

Southern Region Small Fruit Consortium: Http://www.smallfruits.org

Upson, Steve, Noble Foundation: http://www.noble.org/Ag/Research/Horticulture.htm

Some Strawberry Plant Suppliers

Jersey Asparagus Farms
105 Porchtown Rd.,
Pittsgrove, NJ 08318
856-358-2548

Nourse Farms, Inc.
41 River Rd.,
South Deerfield, MA 01373
413-665-2658

Krohne Plant Farms
65295 CR 342
Hatford, MI 49507
269-424-5423

Strawberry Tyme Farms
R.R. #2 Simcoe, Ontario Canada
N3Y4K1
519-426-3099

Ghesquiere Nursery
Simcoe Ontario Canada
519-428-1087

Goodsen Berry Supplies
Little Rock, Arkansas
501-335-8185

Other strawberry nurseries can be found at: www.ncstrawberry.org

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