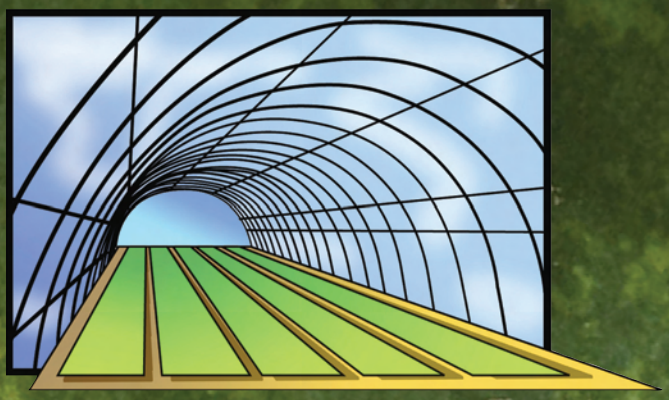
High Tunnel Melon and Watermelon Production



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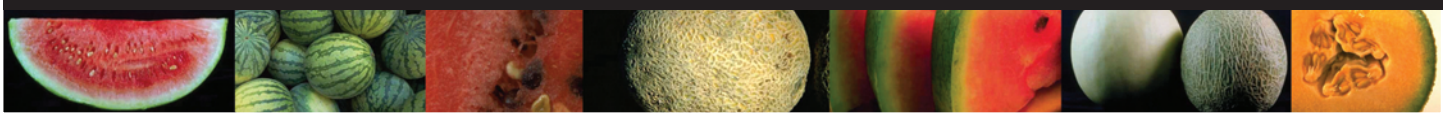


High tunnels are low-cost, passive, solar greenhouses that use no fossil fuels for heating or venting (Figure 1). High tunnels can provide many benefits to horticulture crop producers:

- High tunnels are used to lengthen the growing season of crops.
- High tunnels protect the growing crop from environmental stress such as drought, driving rain, wind and temperature extremes.
- High tunnels protect crops from insect and disease invasion.
- High tunnels are well suited for producing heirloom and specialty vegetables that require a specific growing environment.
- High tunnels permit intensive crop production on a small area of land.

Many warm-season (frost-sensitive) vegetable crops can be grown in a high tunnel. Cucurbits are a large, diverse group of warm-season plants in the Cucurbitaceae family. Cucurbits include many popular vegetables such as cucumber, gourd, cantaloupe (muskmelon), squash, pumpkin and watermelon and are an important dietary source of fiber, minerals, beta-carotene and vitamin C.

Botany

Cantaloupe or muskmelon (*Cucumis melo* L.) and watermelon (*Citrullis lanatus* var. *lanatus*) are annual plants with a trailing vine growth. *Cucumis melo* has several botanical subgroups (Table 1). In the United States, *reticulatus* and *inodorus* are commercially grown, while the remaining groups are grown for niche or local markets.

The cantaloupe fruit that most Americans are familiar with is not actually a true cantaloupe. A true cantaloupe has no netting on the rind, is often warty, and many will not abscise or slip from the vine when mature (Figure 2). True cantaloupes are widely grown in Europe and include varieties such as *Charentais*, *Prescott*, *D'Alger* and *Petit gris de Rennes*.

A muskmelon (*Cucumis melo* var. *reticulatus*) has a pronounced netting on the fruit, is aromatic, and slips from the vine when mature (Table 1). Most wholesale markets prefer an oval to round muskmelon with medium to heavy netting and slight ribbing, while some local markets prefer lightly netted, deep-ribbed types. The terms *muskmelon* and *cantaloupe* are often used interchangeably in U.S. markets.

Galia melons are green-fleshed, aromatic muskmelons with a golden-yellow, netted rind (Figure 2). Galia melons are adapted to warm, dry climates and are often called desert melons. Rainfall during flowering and fruit formation significantly lowers the quality of Galia melons.

Watermelons are classified as seeded diploids or seedless triploids. Seedless watermelons have higher production costs but may be profitable as an early-season crop in a high tunnel. A seedless watermelon is a cross between a diploid (two sets of chromosomes), seeded variety and a tetraploid (four sets of chromosomes) line. The resulting

Figure 1. High tunnels are plastic-covered, solar greenhouses that can be used for early-season cucurbit production.

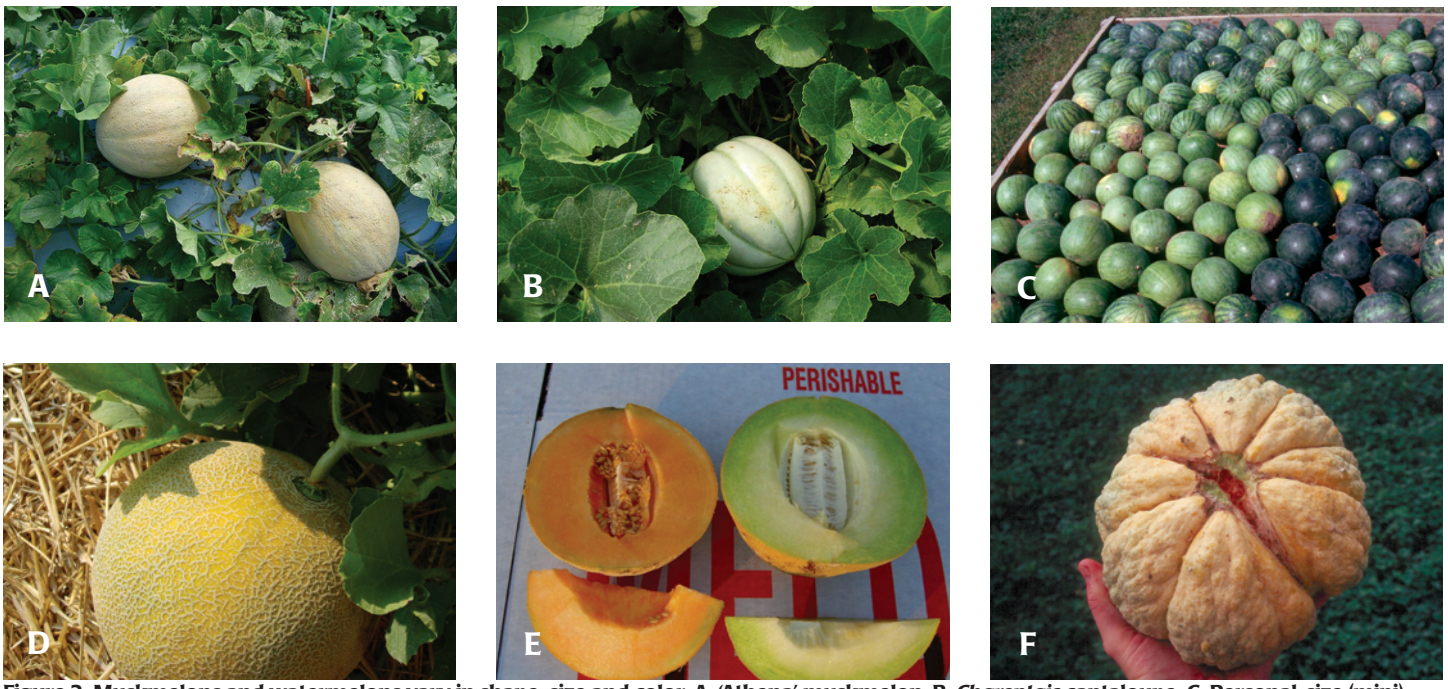


Figure 2. Muskmelons and watermelons vary in shape, size and color. A. 'Athena' muskmelon. B. *Charentais* cantaloupe. C. Personal-size (mini) seedless watermelons. D. *Galia* muskmelon. E. *Athena* (left) and *Galia* 152 (right) muskmelon flesh. F. *Prescott* cantaloupe.

plant is sterile with three sets of chromosomes. Seedless cultivars must have pollen from a seeded, diploid cultivar to set fruit. Mini seedless watermelons (less than 6 pounds) are becoming popular with consumers as single-serving melons. Melons and watermelon are second only to bananas in total U.S. per capita consumption of fresh fruit. Melons are low in fat and sodium, have no cholesterol, and provide many essential nutrients such as potassium. Watermelons are an excellent source of lycopene, which is credited with reducing many forms of cancer.

Both melons and watermelon are native to Africa and thrive in a warm, dry climate with a long growing season. The optimal growing temperature for melons and watermelons is 70–85 degrees F.

Cucurbits have palm-shaped leaves that are lobed (watermelon) or nonlobed (cantaloupe). Leaves are arranged in an alternate pattern on the vine. The vines are angular and hairy with several lateral branches that in turn have many secondary branches. Vines can reach a length of 30 feet for some cucurbit varieties.

Melons and watermelons have modified, threadlike leaves called tendrils, which the vine uses for anchoring or climbing (Figure 3). Tendrils can be branched (watermelon) or simple (muskmelon). Both cucurbit crops have strong taproots that can be deep on nonirrigated melons but generally are shallow but horizontally extensive when the crop is adequately irrigated.

Cucurbit flowers are diverse in color, shape and size (Figure 4). Cucurbits have a monoecious flowering pattern, which means male and female flowers are separate on each plant. Melons have male (staminate) flowers and a mix of female (pistillate) and perfect (both male and female organs) flowers. Watermelons typically have staminate and pistillate flowers. Staminate flowers appear

Table 1. Groups of *Cucumis melo*.

Cucumis melo subgroup	Cultivar examples	Fruit characteristics
Cantaloupensis (true cantaloupe)	*Prescott melon* *D'Alger* *Charentais*	Smooth to warty fruit surface. Very aromatic. No netting. Fruits do not slip from vine when mature. Widely grown in Europe
Inodorus	*Canary melon* *Casaba melon* *Crenshaw melon* *Honeydew melon*	Not aromatic. Fruit does not slip from vine when mature. Flesh is usually green or white.
Reticulatus	Muskmelons *Persian melon* Galia melon	Netted and aromatic fruit slips from the vine when mature.
Conomon	Makuwa uri *Chinese melon* *Sakata's sweet*	No aroma. Fruit has crisp, white flesh. Widely grown in Asia.
Flexuosus	*Armenian cucumber* *Snake melon*	Elongated fruit with no aroma.
Chito	*Mango, Lemon melon*	Fruit is not sweet or aromatic.
Dudaim	*Queen Anne's Pocket Melon*	Very aromatic fruit.

Figure 3. Watermelon leaves (left) are lobed with branched tendrils while muskmelon leaves (center) are nonlobed with simple tendrils at each leaf axis. Tendrils are used by the vines for climbing and anchoring (right).

Figure 4. Melon flowers (left) are brighter yellow and yield more nectar than watermelon flowers, (center and right).

Figure 5. Mini seedless watermelons are similar in size to muskmelons (3–6 pounds).

first and are followed by emergence of more staminate and pistillate flowers. Generally, 12 to 15 staminate flowers are produced for each pistillate flower.

Cultivar selection

There are many productive cantaloupe and watermelon cultivars that can be grown in a high tunnel (Figure 5, Table 3). Choose a suitable cultivar for your market outlet. Purchase high-quality, vigorous seed for transplant production. (See Appendix for a list of seed suppliers). High-quality seed means faster germination and vigorous growth. One ounce of muskmelon seeds contains 950 to 1,200 seeds while one ounce of watermelon seeds contains 300 (large-seeded cultivars) to 650 (small-seeded cultivars) seeds (Table 2).

Table 2. Seeds required for transplant production

Vegetable	Plants/oz of seed*
Cantaloupe	500–600
Cucumber	500–600
Pumpkin	200
Summer squash	200–300
Watermelon	200–400

*Graded transplants.

Table 3 includes suggested varieties of muskmelons, cantaloupes, honeydews and mini seedless watermelons for high tunnel production.

Table 3. Potential melon and mini watermelon cultivars for high tunnel production.

Cultivar	Cucurbit type	Days to maturity	Fruit description	Disease tolerance
Athena	Muskmelon	80	Oval/round fruit with minor netting and no sutures.	$PM_{1,2}$ $F_{0,1,2}$
Aphrodite	Muskmelon	75	Oval, large fruit. Light sutures.	$PM_{1,2}$ $F_{0,1,2}$
Ambrosia	Muskmelon	86	Round fruit. Coarse netting. Good garden cultivar.	PM
Crescent Moon	Muskmelon	73	Large, eastern-type melon.	PM_{12}
Jenny Lind	Muskmelon	70	Round fruit with heavy netting. Green or orange flesh. Large blossom scar. Heirloom melon.	—
Odyssey	Muskmelon	80	Round, large fruit with coarse netting and shallow sutures	$PM_{1,2}$ $F_{0,1,2}$
Primo	Muskmelon	78	Small, western-type shipping melon. Heavy netting	PM_{12}
Arava	Galia	77	Round fruit with green flesh. Light netting.	PM
Galia 152	Galia	80	Round fruit with green flesh. Very aromatic. No sutures.	$PM_{1,2}$ $F_{0,1,2}$
Galileo	Galia	83	Round fruit with green flesh. Light netting.	$PM_{1,2}$ $F_{0,1,2}$
Gallicum	Galia	80	Round fruit with green flesh. Small fruit.	$PM_{1,2}$ $F_{0,1,2}$
Lavigal	Galia	80	Round fruit with green flesh. Very aromatic. Light netting.	$PM_{1,2}$ $F_{0,1,2}$
Early Dew	Honeydew	80	Round fruit. Very early, 2.5–3 lb fruit which slips at maturity.	$PM_{1,2}$ $F_{0,1,}$
Honey Orange	Honeydew	74	Oval fruit with orange flesh.	$PM_{1,2}$ $F_{0,1,}$
Honey Star	Honeydew	85	Round fruit with light-green flesh.	$PM_{1,2}$ $F_{0,1,}$
Savor	Charentais cantaloupe	78	Round, small fruit with dark orange flesh. Produces a vigorous vine that may need pruning	PM $F_{0,1,2}$
Watermelon (mini size)				
Sweet Beauty	Mini seeded	77	Small, oblong, seeded watermelon	—
Extazy	Mini seedless	85	Small, round	—
Hazera 5130	Mini seedless	85	Small, round	—
Mohican	Mini seedless	85	Medium, green rind	—
Solitaire	Mini seedless	85	Small, round	—
Vanessa	Mini seedless	80	Solid, dark rind	—

PM = Powdery mildew race 0, 1, 2. F = *Fusarium* race 0, 1, 2.
Note: This list is not intended to include every cultivar that may perform well in a high tunnel.

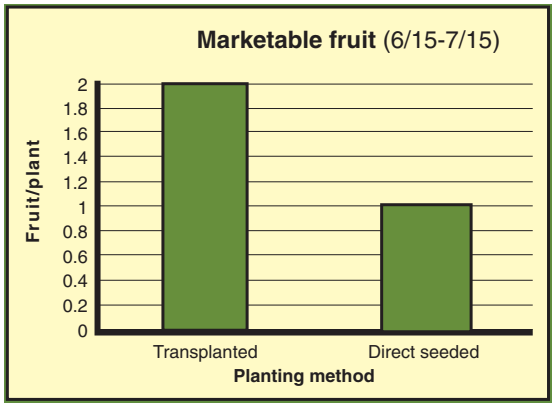


Figure 6. Transplants increase early yield of melons in a high tunnel.

Transplant production

For early production in a high tunnel, melons and watermelons should be established as transplants. Transplants increase uniformity and earliness of the crop while reducing seed costs (Figure 6). Quality transplants begin with quality seed. Choose a suitable cultivar and melon type that has consumer demand in your market outlet (Table 3).

Various containers can be used to germinate and grow cucurbit plants. Generally a transplant container or cell 1 to 2 inches in diameter is optimal for melon and watermelon. However, using a larger cell size may increase earliness. One seed can be placed in each container cell, one-half inch deep using a standard potting or germination mix. Seedless watermelon seeds are planted with the radicle tip pointed up or flat, which helps the seed shed the seed coat. After seeding, water the seeds and place in a warm room (85–90 degrees F) for about three days to accelerate ger-

Table 4. Ounces of fertilizer/100 gallons of water.

Nitrogen (ppm)	Fertilizer analysis			
	20-20-20 (oz)[z]	*9-45-15 (oz)*	*15.5-0-0 (oz)*	*15-30-15 (oz)*
100	6.7	14.8	8.6	8.9
200	13.3	29.6	17.2	17.8
300	20.1	44.4	25.8	26.7
400	26.6	59.2	34.4	35.6
500	33.5	74.0	43.0	44.5
600	40.2	88.8	51.6	53.4

[z] Ounces of fertilizer dissolved in 100 gallons of water.

Figure 7. Use healthy, vigorous transplants for early melon and watermelon production in a high tunnel.

mination. Do not overwater seedless triploids. Seedless watermelons should be germinated at 90 degrees for 48 hours. After 10 percent of the seeds have emerged, the temperature can be lowered to 70–80 degrees (day) and 65–70 degrees (night) for growth and development.

Depending on prevailing weather, transplants should be regularly watered. Watering should be done in the morning allowing leaves to dry before evening, which reduces the risk of disease. Three times a week, a 200 ppm nitrogen solution can be applied to the growing transplants (Table 4). Four to six weeks are required for growth of melon and watermelon transplants. One week before transplanting, reduce fertilization and watering to harden or condition the plants for transplanting within the high tunnel. A good melon or watermelon transplant should have two to four true leaves, short, thick stems and a healthy root system (Figure 7).

Planting in the high tunnel

The soil within the high tunnel should be tilled, fertilized and formed into a raised bed before transplanting (Figure 8). Raised beds (4–6 inches high by 20–32 inches wide) increase the average soil temperature and improve root zone aeration and drainage while providing a larger volume of soil for root growth.

For early melon production, plastic mulch is more effective in warming the soil than organic mulches. Plastic mulch and drip irrigation should be applied to the raised beds at least two weeks before transplanting. There are several plastic mulches to choose from. Black plastic is the preferred plastic mulch for cucurbits because it warms the root zone and both reduces weed germination and soil moisture evaporation. The soil temperature during the daytime is about 5 degrees F warmer at the 2-inch depth under black plastic than in nonmulched, bare soil. Clear plastic mulch warms the soil more than black plastic but does not suppress weed germination. Infrared (IRT) mulch is intermediate between clear and black with the added benefit of reducing most weed emergence. Reflective or metallic mulches repel insects such as aphids but generally keep the soil cooler. White or white-on-black mulch is used to cool the soil and can be used for summer or fall cucurbit plantings within the high tunnel. All plastic mulch should fit tightly over the raised bed to maximize heat transfer from the mulch to the soil. Embossed plastic (embossed with a diamond-shape pattern) mulch fits tightly over the raised bed and expands and contracts without losing tautness. Transplants can be lost from heat necrosis that occurs when heat funnels out through the planting hole when the plastic

Figure 8. Plastic mulch on raised beds accelerates melon growth in a high tunnel.

mulch is not tightly fitted over the raised bed.

In a high tunnel, melons and watermelons are spaced 24 to 36 inches between plants within each row, and the rows are spaced 40 to 48 inches on center. On a square foot basis, this is nearly double the plant density of field-grown melons and watermelons. The ability to grow the plants vertically by trellising and the dry (no rain) environment make higher plant populations feasible within a high tunnel. Thus a commercial high tunnel (2,500 ft^2) can accommodate 200 to 300 cantaloupe or watermelon plants.

Each transplant is planted about 1 to 2 inches deeper than the surface of the transplant root ball. The planting hole on the plastic mulch can be perforated by hand or using a bulb planter. Immediately after transplanting, a starter fertilizer solution containing nitrogen (200–400 ppm) and phosphorus should be applied to each transplant to reduce transplant shock.

Planting date varies with geographical region. Soil temperature is a reliable index for determining when to plant within a high tunnel. Melons and watermelons can be transplanted when the soil temperature at the 2-inch depth is at least 60 degrees F.

Row covers

Row covers are used to increase the average minimum temperature within the crop canopy. There are two types of row covers. One type is polyethylene plastic with perforated holes for ventilation, and the other type is a spunbonded fabric. Spunbonded row covers (0.5–1.25 oz/yd^2) are recommended for high tunnel Cucurbit production (Figure 9). Unlike polyethylene row covers, spun bonded row covers do not produce extremely high air temperatures during the daytime and are more effective at retaining heat for frost protection during the night. In addition, spunbonded row covers are lightweight, which makes them easy to place on or remove from the crop canopy.

Figure 9. Row covers protect melons from frost damage and chilling injury.

Row covers should be applied immediately after transplanting in the spring and can be kept over the crop for several weeks depending on temperature within the high tunnel. In Missouri, row covers are left on the plants for about three weeks and are removed when the melons and watermelons begin to flower in mid-April. They are not completely removed from the high tunnel but held in reserve if a frost or freeze threatens the crop.

Soil management and fertilization

Before planting cucurbits within a high tunnel, the soil should be sampled and analyzed to determine pH, organic matter content and nutrient levels. The optimal pH range for cantaloupes and watermelons is 6.0 to 6.8. If the soil pH is below optimum, liming may be performed. If necessary, lime should be applied as far in advance of transplanting as possible.

Before transplanting, 7 to 11 ounces of nitrogen per 1,000 ft^2 should be applied to the raised beds. Based on a soil test, all the required phosphorus and half of the required potassium should be applied before transplanting and mulch application. If the soil within the high tunnel is high in organic matter (at least 3 percent), a lower rate of preplant nitrogen can be applied. Thoroughly incorporate the fertilizer in the top 4 to 6 inches of the soil. Applying water-soluble fertilizer through the irrigation system is referred to as *fertigation*. If no fertilizer is applied before planting, fertigation should begin immediately after transplanting in the high tunnel. However, if preplant fertilizer is applied, fertigation can be delayed for two weeks. Fertilizer can be applied through the drip irrigation system over the remaining 10- to 12-week growing season. Table 5 gives a suggested fertigation program for high tunnel melons and watermelons. If preplant potassium is applied, potassium fertigation commences three weeks after transplanting. Adequate potassium fertilization is crucial for melon crops because potassium is correlated with melon sweetness.

Fertilization rates should be based on the *total effective mulched area*. Measure the width of the raised bed covered with plastic, and multiply by the row length. This product is multiplied by the number of rows within the high tunnel, which equals the *total effective mulched area* per high tunnel.

Table 5. Suggested nitrogen and potassium fertigation schedule for high tunnel melons and watermelons.

Days after transplanting	Weekly nitrogen (oz/1,000 ft^2)	Weekly potassium[z] (K_2O) (oz/1,000 ft^2)	Cumulative nitrogen (oz/1,000 ft^2)
Preplant	9.2	18.4	9.2
14–21	2.3	0	11.5
22–49	3.3	6.7	24.7
50–77	3.9	7.7	40.3
77–84	1.8	3.6	42.1

[z] Assumes a low soil potassium level.

Irrigation

Because high tunnels exclude natural rainfall, the water requirements of the crop must be supplied by drip irrigation. Drip irrigation is a method of applying water slowly to the root zone of the growing crop by using small, collapsible tubes called drip tape (Figure 10). Drip irrigation has many advantages, including less water use and the ability to supply nutrients to the crop over the course of the growing season. Drip irrigation also helps the crop to grow evenly, reduces weed emergence and keeps the foliage dry, which prevents many diseases.

One drip line (8–10 mil thickness; 4–12 inch dripper spacing) is placed 3 inches from the center of the bed. The drip line should be buried 1 inch to prevent damage by mice and expansion and contraction of the tube during the growing season. Lateral movement of water from the drip tube may be about 10 to 12 inches on either side of the tube in heavy soils and 8 to 10 inches in light soils.

Irrigation can be scheduled based on using a soil moisture sensor (tensiometer or moisture blocks) or systematically applying an even quantity of water each week. Tensiometers work effectively in sandy soils, while gypsum blocks are effective in heavy soils.

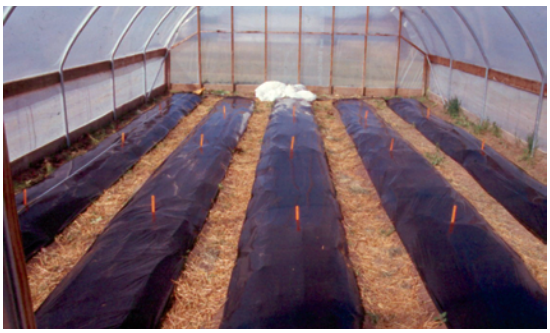


Figure 10. Drip irrigation and black plastic mulch improve melon and watermelon yield and quality.

Generally one inch of water (per acre equivalent) is applied to melons and watermelons each week. During periods of hot weather and a heavy fruit load, 1.5 inches/week can be applied. For example, if a grower is using a medium-flow drip tape with a flow rate of 0.40 gpm/100 ft, and the mulched row width is 30 inches, the crop should be irrigated 6.5 hours *per week* to deliver one inch of water to the crop (Table 6). Because plastic mulch reduces soil moisture evaporation, it is important not to overwater the crops. Excessive irrigation during the latter stages of fruit ripening can lower sugar levels and cause fruit cracking.

Table 6. Hours required to apply 1 inch of water to a mulched, raised bed.

Drip tube flow rate		Width of mulched bed (ft)		
[1]Gph/100 ft	[2]Gpm/100 ft	2.0	2.5	3.0
8	0.13	15.5	19.5	23.5
10	0.17	12.5	16.5	18.5
12	0.20	10.5	13.0	15.5
16	0.27	8.0	10.0	11.5
18	0.30	7.0	8.5	10.5
20	0.33	6.0	8.0	9.5
24	0.40	5.0	6.5	8.0
30	0.50	4.0	5.0	6.0
36	0.60	3.5	4.5	5.0
40	0.67	3.0	4.0	4.5
42	0.70	3.0	4.0	4.5
48	0.80	2.5	3.0	4.0

[1]Gallons of water per hour per 100 ft run of drip tape.
[2]Gallons of water per minute per 100 ft run of drip tape.

Pollination

Melons and watermelons have separate male and female flowers on each vine. Male flowers appear at least a week earlier than female flowers. Female flowers are easy to distinguish from male flowers by the presence of a swollen base below the flower petals (Figure 11A). Flowers open after sunrise and remain open for only one day. Since melon and watermelon pollen is heavy and sticky, it does not move with wind currents. Thus, physical movement of pollen is necessary before a fruit is set on the vine. Pollination of the first flush of female flowers is crucial because these flowers can develop into large, early fruit.

Nectar-collecting bees (honey bees, bumble bees, solitary bees and mason bees) are common vectors of cucurbit pollen. Research has

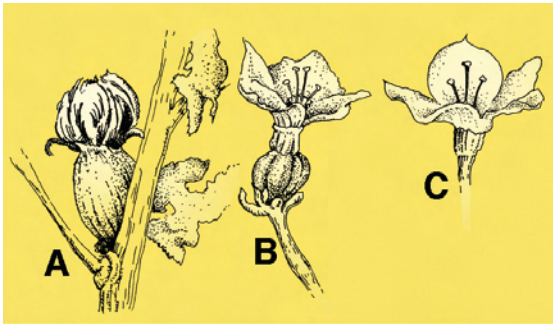


Figure 11. Melons and watermelons require cross-pollination to set fruit. (A) Note the swelling at base of the flower. This will develop into fruit.

Cantaloupe can produce two types of flowers: (B) Perfect flowers having both male and female parts, and (C) Staminate flowers having only male parts.

Source: Auburn University.

revealed that each female melon flower must receive at least eight bee visits to set a marketable fruit. Research at the University of Missouri has revealed that having sufficient bees for pollination will increase average fruit weight of muskmelons within a high tunnel. Bumble bees *(Bombus impatiens)* can be purchased and placed within each high tunnel two to three weeks after transplanting. Use insect screen to retain the bees within the high tunnel. Honey bee colonies can be placed close to the high tunnel to encourage entry. Planting high nectar yielding plants such as *Brassica* sp. (mustards) close to the high tunnel may increase native bee density within a high tunnel. Melons that are poorly pollinated are smaller while improperly pollinated watermelons are often lopsided or bottlenecked.

If feasible, hand pollination of cucurbits may be performed. In midmorning select a recently opened male flower. Carefully remove the petals surrounding the male stamens (pollen-producing organs). Identify a recently opened female flower, and gently brush the stamens against the flower 10 to 15 times. Research indicates that hand pollination is most effective between 6:00 and 9:00 a.m. Hand pollination requires patience and may be effective only 50 percent of the time.

Seedless watermelons produce sterile pollen and thus require pollen from a seeded cultivar before setting fruit. A seeded cultivar can be planted as a single row parallel to the baseboards of the high tunnel. Also, the seeded cultivar can be interplanted with the seedless cultivar with every third plant within the row a seeded cultivar. Icebox watermelon cultivars (7–10 lb fruit) are effective pollenizers for early yield of seedless watermelons. It is important to synchronize appearance of male flowers on the pollenizer cultivar with female flower opening on the seedless cultivar. The icebox pollenizer should be seeded seven to ten days later than the seedless watermelon cultivar, since they flower earlier than most watermelon cultivars. If a standard-sized seeded melon is used as a pollenizer, it should be seeded three to four days before the seedless watermelons are seeded. Watermelons and melons will not cross-pollinate when grown within the same high tunnel.

Pruning

Many melon cultivars produce extensive vine growth. Pruning the vines may be necessary if the melons are trellised. Pruning is performed to achieve a balance between vine growth and fruit set. Pruning increases average fruit weight while reducing the number of unmarketable (cull) fruit.

Each melon vine produces a primary stem or leader with many secondary branches or laterals. A suitable pruning treatment for high tunnel muskmelons to retain the primary stem and one of the first laterals while pruning all additional laterals up to and including the eighth leaf node. All secondary branches after the eighth node can be left unpruned on the plant. This method of pruning permits the vine to be easily trellised either by a nylon net trellis or by using strings and vine clips as in greenhouse tomato production. Prune off any misshapen fruit or fruit that was not pollinated.

Trellising

Training melons and watermelons to grow vertically is referred to as trellising and is one of the advantages of growing melons in a high tunnel. Most melon cultivars and personal size (less than 7 pounds) watermelon cultivars are amenable to trellising. Trellising improves light interception by the crop canopy, makes harvest easier, improves pollination and reduces damage to the vines during harvest. Trellising is necessary if the high tunnel is used to grow crops in addition to melons, since melon vines will overrun other plants if not trained.

Various types of trellises can be used for high tunnel melons and watermelons (Figure 12). Using a trellis with a plastic (nylon) net (6-inch by 7-inch openings) that is about 72 inches

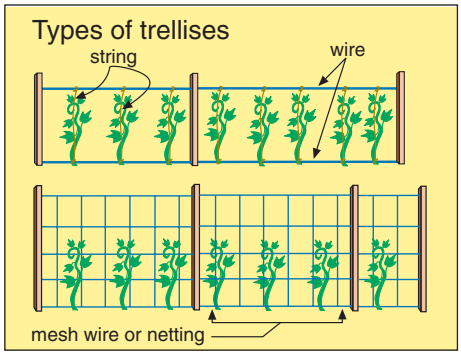


Figure 12. Trellising increases marketable yields of high tunnel melons.

high is a suitable trellis for pruned and unpruned vines. The trellis must be supported by a tensile wire, which runs parallel to the row and slightly higher than the trellis. This wire can be secured to the frame of the high tunnel or attached to posts at each end of the row. The mesh trellis is in turn secured to the wire. The vines gradually grow up the trellis, using their tendrils to cling to the mesh trellis, but they will require training to keep the growth vertical. Assume the static load on the wire will be about 10 to 12 pounds per linear foot.

Another form of trellis is an option when each vine has been pruned to one or two stems. Tie a length of nylon twine to a tensile wire 6 to 7 feet off the ground and secure it to the ground using anchor pins. The primary stem of the muskmelon plant is secured to the twine using plastic vine clips. As the vine continues to grow, it is clipped to the vertical twine. If the vine grows taller than the height of the trellis, it can be trained from the top down on another length of twine. Woven wire fence or livestock panels can also be used as a trellis for cucurbits.

Fruit may require support as it grows on the trellis. Some muskmelon cultivars have fruit with rigid peduncles (fruit stems) and may not need support. Small, mesh bags (onion sacks), cheesecloth or nylons can be used as slings to support the fruit (Figure 13). The bags can be tied to the trellis or the support wire. The bag should allow light penetration and not hold moisture. When the fruit is ripe, the bag can be cut from the trellis.

Figure 13. Mesh bags tied to a trellis protect and support melons as they ripen.

Mini seedless (or seeded) watermelons can be trellised in a high tunnel. If so, the fruit must be supported. Other types of watermelons (large, seeded or seedless) can be grown without a trellis and left to vine throughout the high tunnel.

Harvest and yield

Melons have several yield flushes requiring harvest three to four times a week during peak production, while watermelons tend to ripen evenly and the bulk of the fruit can be harvested in relatively few harvests (Figure 14). Melon and watermelon fruit are ready to harvest 45 to 60 days after flowering. Research at the University of Missouri has shown that Galia muskmelons are very high yielding when grown in a high tunnel (Table 7). Muskmelons yield more fruit per plant than watermelons in a high tunnel. Melon harvest in a high tunnel is four to five weeks earlier than field-grown melons and watermelons in Missouri.

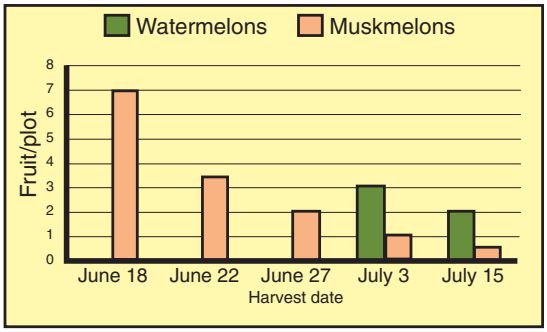


Figure 14. Marketable yield of Galia muskmelon and mini seedless watermelon. Columbia, Mo., 2005. Each plot contained four plants.

Table 7. Average yields of cantaloupes and mini seedless watermelons within a high tunnel. Columbia, Mo.

Melon type	Average market yield/plant (no.)	[1]Average market yield/high tunnel (no.)
Galia	3–5	900–1,500
Charentais	3–4	900–1,200
Athena	2–3	600–900
Micro seedless watermelon	2	600

[1]Assumes a high tunnel with 300 melon or watermelon plants.

Figure 15. Muskmelons slip from the vine when mature. Watermelons, however, do not slip and are harvested when the tendril closest to the fruit dries.

Muskmelons develop a distinct abscission zone between the fruit stem and the fruit (Figure 15). As muskmelon fruit ripens, the color changes from green to yellow, and the fruit produces an aromatic odor on the blossom end. On some cultivars, the netting becomes more pronounced at maturity. High tunnel muskmelons for local markets should be harvested vine ripe or "full slip," the stage at which the fruit detaches from the vine with slight pressure. To prevent overripening, Galia melons should be harvested when the fruit changes color to a bright yellow. Galia melons produce a strong floral odor and easily detach from the stem. Muskmelons will ripen after harvest, but the sugar content does not increase. The sweetness should be at least 11 degrees Brix, and the fruit should weigh 3 pounds or more. Specialty melons can be sold at a smaller weight (1–2 pounds).

Charentais melons and honeydew melons do not slip from the vine at maturity, and honeydews do not produce an aroma as they ripen. Charentais fruit will change color from a gray/green to creamy white. The leaves closest to the fruit stem will also begin to develop a pale color. The fruit must be harvested before it begins to split. Ripe melons can be stored for almost two weeks at 34 degrees F and 95 percent relative humidity. Honeydew melons and other specialty melons should be stored at 45 degrees and 90 percent relative humidity.

Watermelons do not slip from the vine or emit an odor when ripening. Other indicators of maturity include increased "waxiness" of the rind, drying of the tendril closest to the fruit and a dull, muffled sound when the watermelon is thumped, depending on the variety. Watermelons should be cut from the vine rather than pulled, leaving about an inch of stem. The stem can be trimmed on the day of sale, giving the melons a fresh harvest appearance. Harvest early in the morning when field heat is low and the fruits are most turgid. Watermelon sweetness should be at least 11 degrees Brix. Watermelons should be stored at 50 to 60 degrees F and 90 percent relative humidity.

Marketing

Demand for melons and watermelons is increasing. Muskmelons are sold individually in farmers' markets (Figure 16). Most wholesale markets sell melons in corrugated bins or 1¾-bushel boxes that contain 15 to 18 melons per box and weigh about 60 pounds. Muskmelons weighing more than 6 pounds are considered large; medium-size melons weigh 4 to 6 pounds and small melons weigh less than 4 pounds. Watermelons are sold individually or in bins containing about 60 watermelons. Use only clean bins or boxes for packing melons and watermelons.

Pest management

High tunnels are effective in reducing pest outbreaks that routinely occur in the open field environment. Growing crops earlier in the season avoids many pests, which normally become

Figure 16. Melons are boxed for wholesale markets or sold by count in farmers' markets.

Figure 17. Melon aphids congregate on lower leaf surfaces and cause "cupping" of the leaves.

established later in the season. However, insects and diseases can enter and spread within the high tunnel. Maintaining healthy, nonstressed plants, managing the high tunnel environment properly, preserving beneficial insects and early pest detection will prevent many pests from becoming a problem within the high tunnel. The following are some pests detected on high tunnel melons and watermelons in the central Midwest.

Aphids

Aphids are small (1/10 inch long), pear-shaped insects with soft bodies. In the sheltered, humid environment of a high tunnel, aphids are prolific. The melon aphid *(Aphis gossypii)* is the most common aphid that feeds on cantaloupes and watermelons. Melon aphids are typically pale green in the wingless stage and dark black as winged adults (Figure 17). Aphids suck sap or photosynthates from the growing plant, causing it to weaken. Aphids also excrete tremendous volumes of waste material called honeydew, which becomes a black sooty mold on leaf and fruit surfaces. Aphids can transmit many serious cucurbit virus diseases.

Early detection of aphid invasion is crucial in a high tunnel. Scout rows closest to the baseboards or end walls for aphid infection. Generally, aphids can be found on the underside of leaves and at the growing tips of the vines. However, melon aphid can also be observed on lower leaves of the vines as well as the growing tips. Often the growing tips become curled, looking like virus symptoms. Melon aphids can overwinter within a high tunnel. Remove all crop debris from winter production, and destroy any weeds before establishing melons and watermelons in a high tunnel. Carefully inspect transplants to detect any aphids that may have invaded transplants in the greenhouse.

Aphids have many natural enemies, including ladybird beetles *(Hippodamia convergens)*, lacewings *(Chrysoperia rufilabis)* and predatory midges *(Aphidoletes aphidimyza)*. Natural enemies can be released to clean up hot spots in the high tunnel and should not be used as a rescue treatment when aphid numbers are high. Systemic, targeted insecticides (those that translocate within the plant) can be applied at transplanting to provide 30 to 36 days of aphid control. Avoid using harsh, foliar insecticides that may kill beneficial insects in a high tunnel. There are several "soft" insecticides that target only aphids and preserve beneficial insects. Always use a labeled surfactant with each pesticide to increase distribution over the foliage.

Thrips

Thrips (Thysanoptera: Thripidae) are small (1/16 inch long) elongated insects that can be a serious insect pest of high tunnel melons and watermelons. Thrips are usually found clustered in flowers and on the underside of leaves, especially near the terminal growth of the vines. Damage to the plants is caused by adult and nymph thrips scraping the surface of the leaves with their mouthparts and feeding on the exuding sap. The damaged plants will have small, silver streaks on the leaves, and the plant looks as though it has been sandblasted (Figure 18). Fruit can have surface scars from early-season thrips feeding. Thrips, like aphids, can be imported into the high tunnel on transplants.

Always isolate vegetable transplants from ornamental plants in the greenhouse. Early detection of thrips is important. Inspect plants regularly, looking in blossoms or on the underside of terminal leaves. Use blue sticky traps to detect winged adult thrips.

Minute pirate bugs *(Orius insideosus)*, green lacewings and predatory mites are natural enemies of thrips and may be effective in the early stages of a thrips invasion.

However, using beneficial insects and mites will not be effective as a rescue treatment for

Figure 18. Thrips cause significant foliar damage to cucurbits (left, center). Adult thrips (right).

Figure 19. Spotted (left) and striped (center) cucumber beetles are serious pests of melons and watermelons.

Source: *Lee Jenkins Slide Collection, University of Missouri-Columbia*

widespread thrips invasion within the high tunnel. Systemic, targeted insecticides applied at transplanting will be effective in controlling thrips for about 35 days.

Several soft pesticides may be used to control thrips within a high tunnel. Insect exclusion screen can be used to cover the high tunnel vents and prevent invasion of thrips.

Cucumber beetles

Spotted cucumber beetle *(Diabrotica undecimpuntata howardii* (Barber)) and striped cucumber beetle (*Acalymma vittata* (Fabricius)) are serious insect pests of field-grown cucurbits in the central Midwest. Cucumber beetles are ¼-inch-long beetles with either 12 spots (spotted cucumber beetle) or three black stripes (striped cucumber beetle) on their abdomens (Figure 19). Both species can overwinter in Missouri and become active in April when daytime temperatures exceed 55 degrees F.

Adult beetles begin feeding on cotyledons (seed leaves) of transplants and continue to feed on the emerging leaves, stems, flowers and eventually the fruit surface (watermelon). Both species can transmit bacterial wilt *(Erwinia tracheiphilia)* to cantaloupes and muskmelons (see Figure 23). Watermelons are not susceptible to bacterial wilt.

Within two weeks after transplanting, begin scouting for cucumber beetles in the high tunnel. Use yellow sticky traps to detect cucumber beetles.

Cucumber beetles are very mobile. Insect exclusion screens can be used to control cucumber beetles entry into the high tunnel. Systemic insecticides applied as a post transplant drench will provide about 35 days of control, which is long enough to reduce bacterial wilt infection. Further control through the growing season can be accomplished by applying foliar insecticides. Avoid using insecticides that may be toxic to pollinating insects. There are no effective biological control techniques for cucumber beetle.

Whiteflies

Greenhouse whitefly (*Trialeurodes vaporariorum* (Westwood)) is the most common whitefly species that can infest high tunnel melons and watermelons. Whiteflies are small (1/16 inch long), soft-bodied insects with wings covered with white, powdery wax. Whiteflies damage plants by sucking the sap and transmitting harmful viruses. Much like aphids, they excrete honeydew, which develops into sooty mold on the vines and fruit. In the central Midwest, whiteflies can appear within the high tunnel in late summer. Scout plants regularly, and check the underside of the


Figure 20. Whiteflies are late-season pests of high tunnel melons.

leaves of new foliage for whitefly adults (Figure 20). Yellow sticky traps are useful in detecting whitefly population levels in the high tunnel. Natural enemies of whitefly include a parasitic wasp *(Encarsio formosa)*, and Delphastus beetles *(Delphastus catalinae)*. Several biological and soft pesticides are labeled for control of whitefly.

Spider mites

Spider mites are small (1/50 inch long), oval-shaped arthropods related to spiders. The most common spider mite on high tunnel melons and watermelons is the twospotted spider mite *(Tetranychus urticae)* with two dark spots on the abdomen (Figure 21). Mites can be found on the underside of leaves where they congregate and suck sap from the plant. The leaf surface develops a scratchlike appearance and interveinal yellowing or bronzing develops (Figure 21). Eventually the leaves die, and the plant becomes progressively weakened. As the population of mites increases, they develop a webbing around the area where they feed and lay eggs. Mites thrive in hot, dry climates (at least 80 degrees F and less than 50 percent relative humidity) and thus become a problem on high tunnel melons and watermelons from midseason onward in the Midwest.

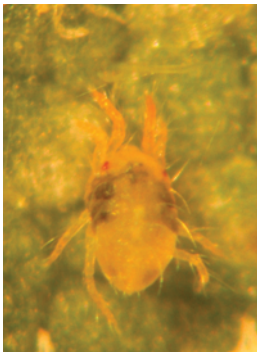



Figure 21. Twospotted spider mites thrive in hot, dry conditions. Source: F. Lam

The twospotted spider mite overwinters in the Midwest and will infest early-season melons in a high tunnel if all weeds and other residue are not removed before establishing the melon or watermelon crop. Clean mowing of vegetation around the high tunnel will reduce the risk of spider mite movement into the high tunnel. Exclusion screening will prevent or reduce spider mite invasion. Spider mites have several natural enemies. Miticides can be used to control the twospotted spider mite. Most miticides will not kill mite eggs, so the first and second spray application should be relatively close together to kill nymphs and adults, which hatch from eggs laid earlier. Always read the label of the pesticide before application. Surfactants should be used to improve miticide distribution over the crop canopy.

Powdery mildew

The dry, humid and dense plant growth within a high tunnel is optimal for development of powdery mildew. Powdery mildew *(Podosphaera xanthii)* is a fungus that looks like a white mold on leaves (Figure 22). The disease appears on the lower leaves of the vine and gradually spreads through the canopy. The vines become weakened from leaf loss, and fruit size can be significantly reduced. Plants should be regularly inspected, starting at fruit set for powdery mildew. Choose resistant cultivars (Table 3). The high tunnel should be properly vented to reduce relative humidity. Many effective fungicides are labeled for powdery mildew control.

Figure 22. Powdery mildew on cucurbit leaves.

Bacterial wilt

Bacterial wilt *(Erwinia tracheiphila)* is a serious disease of melons. Watermelons are resistant to this disease. Bacterial wilt is transmitted by spotted and striped cucumber beetles that feed on melon foliage. Infected plants exhibit leaf wilting followed by vine collapse (Figure 23). Plants are most often infected at early stages of growth.

Control of bacterial wilt in a high tunnel begins with control of cucumber beetles. Scout regularly for cucumber beetles. Use a systemic insecticide that provides 36 days of cucumber beetle control. Row covers will protect the plants from early-season feeding by cucumber beetles. There are currently no melon cultivars resistant to bacterial wilt.

Figure 23. Bacterial wilt causes vine collapse of melons. Source: D. Egel

Useful references

Midwest Vegetable Production Guide for Commercial Growers, University of Missouri Extension Publication MX384, University of Missouri-Columbia.

Babadoost, M., R. Weinzerl, and J. Masiunas. 2004. ***Identifying and Managing Cucurbit Pests,*** University of Illinois Extension Publication C1392. University of Illinois at Urbana-Champaign.

Granberry, D., W. Kelly, W. Chance, and W. McLaurin. 1994. ***Plasticulture for Commercial Vegetable Production.*** University of Georgia Cooperative Extension Bulletin No. 1108.

Goldman, Amy. 2002. ***Melons for the Passionate Grower.*** Workman Publishing Co. New York, N.Y.

Jett, Lewis W. 2004. ***High Tunnel Tomato Production.*** University of Missouri Extension Publication M170. University of Missouri-Columbia.

Lamont, W. J. (ed.). 2004. ***Production of Vegetables, Strawberries, and Cut Flowers Using Plasticulture.*** NRAES Publication No. 133, Ithaca, N.Y.

Maynard, D. (ed.). 2001. ***Watermelons: Characteristics, Production and Marketing.*** ASHS Press 2001.

Rudisill, A. (ed.). 2005. ***Greenhouse IPM with an Emphasis on Biocontrols.*** Pennsylvania State University.

Zitter, T. A., D. Hopkins, and C. Thomas (eds.). 1996. ***Compendium of Cucurbit Diseases.*** APS Press, St. Paul, Minn.

High tunnel information: **http://hightunnels.org**

Melon price information: ***www.ams.usda.gov/mnreports/HX_FV010.txt***

Melon and watermelon seed sources

Abbott & Cobb, Inc.
P.O. Box 307
Trevose, PA 19053-0307
(267) 525-7037
http://acseed.com

Abundant Life Seed Foundation
P.O. Box 772
1029 Lawrence St.
Port Townsend, WA 98368
(360) 385-5660
http://www.abundantlifeseed.org

Baker Creek Heirlooms
2278 Baker Creek Rd.
Mansfield, MO 65704
(417) 924-8917
http://rareseeds.com

Berlin Seeds
5371 Co. Rd. 77
Millersburg, OH 44654
(330) 893-2091

Bountiful Gardens
18001 Schaefer Ranch Rd.
Wilits, CA 95490
(707) 459-6410
http://bountifulgardens.org

Burgess Seed
905 Four Seasons Rd.
Bloomington, IL 61701
http://eburgess.com

Burrell Seeds
P.O. Box 150
Rocky Ford, CO 81067
(719) 254-3319

Chesmore Seeds
5030 E. Hwy. 36
St. Joseph, MO 64507
(800) 383-0865
http://chesmore.com

Clifton Seed Co.
2586 NC 403 W
P.O. Box 206
Faison, NC 28430
(910) 267-2690

Cook Garden
P.O. Box 535
Londonberry, VT 05148
(800) 457-9703
http://cooksgarden.com

Fedco Seeds
P.O. Box 520
Waterville, ME 04903
(207) 873-7333
http://fedcoseeds.com

Golden Valley Seed
P.O. Box 1600
El Centro, CA 92244
(760) 337-3100

Harris Moran Seed Co.
555 Codoni Ave.
Modest, CA 95357
(209) 549-5208
http://harrismoran.com

Harris Seeds
355 Paul Rd.
Rochester, NY 14624
(800) 544-7938
http://harrisseeds.com

Hazera Seeds
2255 Glades Rd.
Suite 123A
Boca Raton, FL 33431
(561) 988-1315
http://www.hazera.com

Holmes Seeds
2125 46th St. NW
Canton, OH 44709
(800) 435-6077

Johnnys Selected Seeds
955 Benton Ave.
Winslow, ME 04901
(800) 854-2580
http://johnnyseeds.com

Jordan Seeds
6400 Upper Afton Rd.
Woodbury, MN 55125
(612) 738-3422

Morgan County Seeds
18761 Kelsay Rd.
Barnett, MO 65011-3009
(573) 378-2655

Nunhems USA, Inc.
1200 Anderson Corner Rd.
Parma, ID 83660
(208) 674-4146
http://www.nunhemsusa.com

Orsetti Seeds
P.O. 2350
Hollister, CA 95024-2350
(831) 636-4822
http://orsettiseeds.com

Park Seeds
1 Parkton Ave.
Greenwood, SC 29647-0001
(800) 845-3369
http://www.parkseed.com

Peaceful Valley Farm Supply
P.O. Box 2209
Grass Valley, CA 95945
(888) 784-1722
http://groworganic.com

Rupp Seeds
17919 Co. Rd. B
Wauseon, OH 43567
(800) 700-1199
http://www.ruppseeds.com

Sakata Seed
18095 Serene Dr.
Morgan Hill, CA 95037
(408) 778-7758
http://www.sakata.com

Seedway
1225 Zeager Rd.
Elizabethtown, PA 17022
(800) 952-7333
http://seedway.com

Seminis Seeds
2700 Camino del Sol
Oxnard, CA 93030
(866) 334-1056
http://seminis.com

Shamrock Seed Co.
3 Harris Pl.
Salinas, CA 93901
(831) 771-1522
http://www.shamrockseed.com

Siegers Seed
13031 Reflections Dr.
Holland, MI 49424
(800) 962-4999
http://www.siegers.com

Southwestern Seed Co.
P.O. Box 11449
Casa Grande, AZ 85230
(520) 836-7595
http://southwesternseed.com

Stokes Seeds
P.O. Box 548
Buffalo, NY 14240
(800) 263-7233
http://stokeseeds.com

Sugar Creek Seed
P.O. Box 508
Hinton, OK 73047
(405) 542-3920
http://sugarcreekseed.com

Sun Seeds
2210 Stephanie Brooks Rd.
Wenatchee, WA 98801

Syngenta Seeds, Rogers Brand
600 N. Armstrong Pl.
Boise, ID 83704
(208) 327-7252
http://rogersadvantage.com

Wilhite Seed Co.
P.O. Box 23
Poolville, TX 76487
(817) 599-8656
http://wilhiteseed.com

Note: Mention or exclusion of any proprietary product or company does not imply endorsement by University of Missouri Extension.

Sources of high tunnels (hoophouses)

A. M. Leonard
P.O. Box 816
Piqua, OH 45356
Phone: 800-543-8955
www.amleo.com

Atlas Greenhouse Systems, Inc.
P.O. Box 558
Alapaha, GA 31622
Phone: 800-346-9902
www.AtlasGreenhouse.com
e-mail: service@atlasgreenhouse.com

Conley's Greenhouse Mfg.
4344 Mission Blvd.
Montclair, CA 91763
Phone: 800-377-8441
www.conleys.com
e-mail: info@conleys.com

CropKing, Inc.,
5050 Greenwich Rd.,
Seville, OH 44273
Phone: (330) 769-2616
www.cropking.com
e-mail: cropking@cropking.com

FarmTek
1440 Field of Dreams Way
Dyersville, IA 52040
Phone: 800-327-6835
www.FarmTek.com

Grow-It Greenhouse
P.O. Box 26037
West Haven, CT 06516
Phone: 800-932-9344
www.growitgreenhouses.com

Harnois Greenhouses
www.harnois.com
US Distributors include:
Syngenta Inc./S&G Flowers (D)
5300 Katrine Ave.
Downers Grove, IL 60515
Tel: (630) 969-0889
1-(888) 323-7253
Fax: (630) 969-6498
dennis.meisch@syngenta.com

Ledgewood Farm
Edward Person
RFD 1 Box 375
Moultonboro, NH 03254
Phone: (603) 476-8829

Ludy Greenhouses
P.O. Box 141
New Madison, OH 45346
Phone: (937) 996-1921
www.ludy.com
e-mail: bmunchel@ludy.com

Poly-Tex Inc.,
P.O. Box 458
Castlerock, MN 55010
Phone: 800-852-3443
www.poly-tex.com

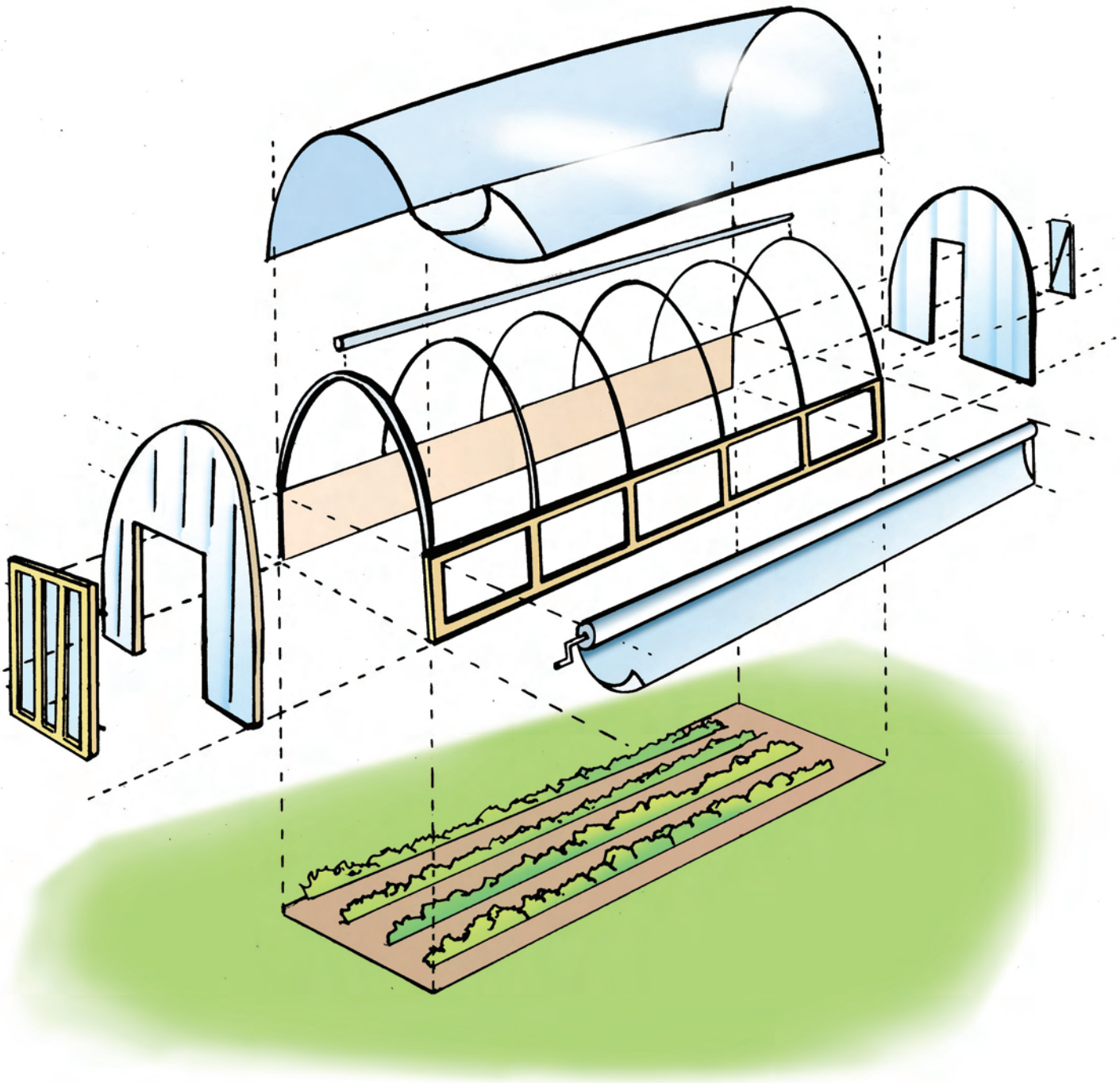
Rimol Greenhouse Systems
40 Londonderry Turnpike
Hooksett, NH 03106
Phone: (877) 746-6544
www.rimol.com

Speedling Inc.
P.O. Box 7238
Sun City, FL 33586
Phone: 800-881-4769
www.speedling.com

Stuppy Greenhouse Mfg.
1212 Clay St.
P.O. Box 12456
North Kansas City, MO 64116
Phone: 800-733-5025
www.stuppyg.com
e-mail: greenhouse@stuppy.com

Turner Greenhouses
P.O. Box 1260
Goldsboro, NC 27530
Phone: 800-672-4770
www.turnergreenhouses.com

Zimmerman's Welding
Jacob L. Zimmerman
16645 Ridgewood Rd.
Versailles, MO 65084
Phone: (573) 378-4770



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