

## **Production of Greenhouse-Grown Peppers in Florida<sup>1</sup>**

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### **Introduction**

In the US, the consumption of high quality red, yellow, and orange bell peppers (*Capsicum annuum*) has been increasing dramatically in the past decade. To satisfy consumers demand, Mexico, The Netherlands, Canada, Israel, and Spain have been exporting high-quality greenhouse-grown peppers into the U.S. In Florida, high market prices, consumer demand, and a suitable environment for growing colored peppers under protected agriculture have encouraged greenhouse growers to consider the economic viability of this crop. In the past years, high quality colored peppers (greenhouse-grown) shipped to Miami averaged year-round wholesale fruit prices 3 times greater than colored field-grown fruits and 5 times greater than field-grown green fruits. With mild winter regions, Florida's greenhouse industry benefits from growing plants and producing fruits under a relatively optimal plant environment during much of the year (Fig. 1).

The total area in Florida with greenhouse-grown peppers expanded to 25 acres in the year 2002. This area could increase in the near future, in part as a consequence of greater demand for specialty vegetable crops, the ban of methyl bromide, and

increases in urban sprawl and subsequent high prices for arable land. For the past 5 years, pepper ranked first in production area in the state's total greenhouse area dedicated to vegetable crops (followed by tomato, cucumber, and lettuce).

A greenhouse production system of peppers differs greatly from the traditional field pepper cultivation system where plants are grown on polyethylene-mulched beds and with drip irrigation, and where fruits are typically harvested at the mature green stage of development (Fig. 2).

Depending on the region's climate and crop-growing season, greenhouses can be a means to economically maintain a warm environment during cool seasons, to protect pepper plants from rain, wind, and high solar radiation, and to retain pollinators and beneficial insects while excluding unwanted insect pests (Fig. 3). In greenhouses, pepper fruits are harvested with full maturation color (Fig. 4), and fruit yields are greater, of higher quality, and usually produced at a time of the year when production in the field is not possible and market prices for peppers are highest.

1. This document is HS979, one of a series of the Department of Horticultural Sciences, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date: July 2004. Please visit the EDIS Web site at <http://edis.ifas.ufl.edu>.

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**Figure 1.** High quality colored bell peppers can be produced in high-roof, passively ventilated greenhouses. Credits: Elio Jovicich



**Figure 2.** Field grown bell peppers in south east Florida where fruits are harvested at the mature green stage. Credits: Elio Jovicich

Marketable fruit yields will vary with greenhouse location, growing season, plant density, trellis system, cultivar, irrigation, and fertilizer management. Current marketable fruit yields of 1.6 to 3.0 lb per square foot and potential yields of 4 lb/ft<sup>2</sup> can be obtained in Florida in passive ventilated greenhouses with low use of fuel for heating. However, because of the higher costs involved with greenhouse growing systems compared to growing in the open field, greenhouse growers have to manage their crops to maximize fruit yield and quality while minimizing production costs per unit of greenhouse floor area.

The production of soilless greenhouse-grown bell peppers, along with the production of other specialty crops such as strawberries, Galia melons, and Beit Alpha cucumbers, have been and continue being researched at the Horticultural Sciences Protected Agriculture Center (<http://www.hos.ufl.edu/ProtectedAg>) at the University of Florida, IFAS, to provide information and assist existing and intending greenhouse growers.



**Figure 3.** Greenhouse-grown peppers in Florida for harvesting fruits during an extended growing season. Credits: Dr. Steve Sargent



**Figure 4.** Greenhouse-grown bell pepper ready to be harvested. Credits: Elio Jovicich

## Greenhouse Structures

In Florida, there is a trend currently for using high-roof, passively ventilated greenhouse structures (13-ft high or more to the roof gutter) for protected vegetable production (Fig. 5).

The greenhouses are covered with polyethylene, which is replaced every 3-4 years. The polyethylene

is a UV-absorbing type of film which can reduce the spread of insect pests and virus diseases in covered crops. The polyethylene film also prevents water condensation from forming on the film surface. The side walls and roof vents can be covered with insect screens (50 mesh) to restrict the entrance of pest insects and to keep beneficial insects, such as bumblebees (*Bombus spp.*), within the greenhouse.

These high-roof greenhouse designs are less expensive and more suited to be used in regions with subtropical and tropical climates than structures covered with glass or polycarbonate. Costs of passively ventilated greenhouses can range as much as 80% less per square foot than the types of greenhouses that seek maximum climate control. Greenhouses with passive ventilation and heating provide a level of climate control that enables plants to survive and produce at economically sufficient yields.

## Cultivars

The sweet pepper cultivars most commonly used in greenhouse production are hybrids that have bell-shaped or blocky-type fruits, with red, orange, or yellow color when they are mature (Fig. 6). Cultivars which produce purple, brown, or white fruit are less commonly grown, as they have less market demand. Cultivars should be selected for a grower's ability to market them as well as pest and disease resistance or tolerance, low susceptibility to fruit disorders, and yield and quality performance. Some of the commonly used cultivars are Parker, Triple 4, Cubico, and Lorca for red; Kelvin, for yellow; and Neibla, and Emily, for orange fruits. New pepper cultivars for greenhouse production are introduced every year by seed companies. For short season crops, some local growers have been evaluating the performance of field pepper cultivars grown under greenhouse production systems.

In a pepper cultivar trial conducted in a passively ventilated greenhouse in Gainesville, the total marketable yield was acceptable for all 23 cultivars tested when grown and harvested during the winter months in north central Florida (manuscript by Shaw and Cantliffe (2002) accessible at <http://www.hos.ufl.edu/protectedag/>



**Figure 5.** Passively ventilated greenhouse at the Horticultural Sciences Protected Agriculture Center, Plant Science Research and Education Unit, UF, IFAS, Citra, FL. Credits: Elio Jovicich



**Figure 6.** Bell pepper fruits from cultivars that mature to different colors. Credits: Elio Jovicich

PepperCultivars2000.pdf). The red and yellow cultivars produced fruit yields of 1.8 to 2.2 lb per ft<sup>2</sup>, the orange cultivars had yields of 1.4 to 2 lb per ft<sup>2</sup> and the chocolate and purple cultivars produced 1.6 lb per ft<sup>2</sup>. When comparing cultivars for those with the highest yield and fruit quality characteristics with low amounts of culls or other disorders, the best red cultivars were Lorca, Torkal, Triple 4, and Zambra; yellow cultivars were Pekin, Kelvin, Neibla, Bossanova, and Taranto; and orange cultivars were Paramo, Lion, and Boogie. Both Choco and Mavras produced high yields and quality fruit, which may be desirable for specialty market production.

### Growing Seasons

The most common greenhouse pepper production season extends from mid July or early August to May. Long crops of up to 300 days are transplanted during the second or third week of July

with a first harvest about the middle of October, ending in late May. Depending on fruit prices and on the quantity and quality of the fruits harvested, production may be extended until June. In Table 1, three production schemes for greenhouse-grown peppers that have been used in Florida are presented.

High temperatures and humidity during July and August adversely affect production but are good for young plant growth. With some cultivars, percentages of unmarketable fruits increase during the late spring, mainly due to a higher incidence of blossom-end rot and fruit cracking. Fruit set can also be low during summer due to high rates of flower abortion under high temperatures. Air ventilation and shade materials for 30% shade help reduce high temperatures during the late spring, summer, and early fall. Cold weather during winter can also adversely affect the set of marketable fruits due to poor pollination, and delay maturation and earliness in production. In central and north Florida, optimum daytime temperatures required for pepper production can be easily achieved in winter while optimum night temperatures cannot and, therefore, heating during the night may be necessary to increase fruit yield and improve fruit quality.

### Soilless Culture Systems

Greenhouse pepper crops in Florida are grown in soil-less culture. Thus methyl bromide is not needed, yet problems with soil borne diseases, and insect and nematode pests are avoided. The plants are grown in containers filled with soil-less media such as perlite,

pine bark, or peat mixes. The media can be reused for several crops (two to three) if disease contamination does not occur. The containers used are nursery pots (3 and 4 gal) with one plant per pot (Fig. 7), or flat polyethylene bags of about 3 ft long (5 gal) with 3 to 4 plants per bag. The plant containers can be aligned in single or double rows, one next to the other one, leading to plant population densities of 0.27 to 0.36 plants per square foot.



**Figure 7.** Pepper plants grown in 3-gal nursery pots filled with pine bark, and irrigated with a complete nutrient solution. Credits: Elio Jovicich

In local trials with greenhouse-grown peppers, fruit yields from plants grown in 3-gal pots or 5-gal flat bags have been similar. Also, similar marketable fruit yields were harvested from plants grown in various substrates, such as perlite, pine bark, or peat-perlite mixes. Pine bark, milled and sieved to particle sizes smaller than one square inch, has shown to be a promising medium because of its low cost, availability, lack of phytotoxicity, and excellence as a plant production media.

### Irrigation and Fertilization

Pepper plants in soil-less culture are fertigated frequently with a complete nutrient solution. Nutrient solution concentrations are similar to those used for tomatoes grown in soil-less culture. The concentrations of most of the nutrients required by pepper plants in larger quantities are increased with plant growth. For example, in the irrigation solution used with soil-less culture, the concentration of nutrients in parts per million (ppm, being 1 ppm = 1 mg per L 1 oz per 7,462.7 gal) can be for N: 70, P: 50,

K: 119, Ca: 110, Mg: 40, and S: 55, starting when transplanting the seedlings. In plants at full production, the nutrient concentration levels can reach N: 160, P: 50, K: 200, Ca: 190, Mg: 48, and S: 65 ppm, respectively. The irrigation solution also provides the plants with micronutrients. The pH of the irrigation solution is maintained at values between 5.5 and 6.5, and the EC, depending on the nutrients concentration levels, will have values between 1.5 and 2.5 mS per cm.

At the time of transplanting, seedlings can be irrigated about 10 times per day delivering about 1.3 fl oz per irrigation event. As plants grow and season temperatures increase, irrigation frequency and volume per irrigation event can be increased up to 40 times per day and 2.5 fl oz per irrigation event, respectively. During full production and under intense sunlight (warm weather), volumes of nutrient solution per plant per day may reach up to 1.5 gal. Irrigation events can be scheduled by using different control systems such as a time clock, a starter tray, or a controller that irrigates based on solar radiation. An excess of irrigation leading to 15 or 20 % drainage from the container at the end of a day ensures sufficient solution delivery throughout the crop and avoids a high concentration of salts in the soil-less media. Systems for recycling the fertigation solution are available and provide a more sustainable use of water and nutrients. With these “closed” irrigation systems, the solution that drains from the pots is sanitized and then the pH and EC are corrected to meet the plant needs. Subsequently, the nutrient solution can be recycled on the same pepper crop.

### Transplanting

Deposits of salt at high levels and excessive irrigation near the cotyledonary node level can promote localized epidermal injuries on a swollen stem base where then fungal infections lead to basal stem rots and sudden plant wilts. This phenomenon (symptoms of basal stem swelling and epidermal wounds at the base of the stem) has been named “Elephant's foot.” For more information on the “Elephant's foot” disorder, please refer to this UF/IFAS Extension publication, “*Elephant's Foot, a Basal Stem Disorder in Greenhouse-Grown Bell Peppers,*” at <http://edis.ifas.ufl.edu/HS206>. To avoid

injuries to the plant stem below the cotyledonary leaves, seedlings (about 35 days-old, 5-7 true leaves) should be transplanted into the soilless culture substrate to the depth of the first leaf node. To reduce creating a humid environment close to the base of the stem, irrigation emitters placed near the seedling stems at transplanting can be gradually moved back (2-3 inches) from the base of the pepper plants over a three week period.

## Pruning and Training

Greenhouse pepper cultivars generally have an indeterminate pattern of growth. Because the plants can grow up to 6-ft tall during a growing season of 250 days, they need to be supported vertically. Pepper plants can be trellised to the Dutch “V” system or to the “Spanish” system (Fig. 8).

Trellising plants with the “V” system consists of forming a plant with two main stems by removing one of the two shoots developed on each node and leaving one or more adjacent leaves per node. The pairs of stems are kept vertically by the use of hanging twines that are wound around the stems as they grow. The “V” trellis system is used by Dutch and Canadian growers.

Spanish, Israeli, and some Mexican growers generally trellis the pepper plants using the “Spanish” system. In the “Spanish” trellis system, the plant canopy is allowed to grow without pruning. The plants are vertically supported by a structure of poles and horizontal twines extended on both sides of the plant rows. Labor requirements for the Spanish system are reduced minimally by 75% of the labor used compared with the “V” trellis system. In a spring crop in Florida, total marketable fruit yields were similar regardless of the trellis system. Moreover, the yield of extra large fruits was actually greater in the plants trellised to the “Spanish” system than in the “V” trellis system. The percentage of fruits with blossom-end rot at the end of the spring was also lower in the nonpruned plants.

## Pollination

Pepper flowers are self pollinated, but the use of bumblebees inside the greenhouse help to ensure the set of high quality fruits, especially during the cool season when pollen viability is lower (Fig. 9). Bumblebees feed on nectar and pollen and their daily activity is naturally timed with the period when flowers are ready to be fertilized. Although one bumblebee hive (containing about 60 bees) per 16,000 square feet might seem costly to the grower, pollination done by workers would be less efficient and much more expensive. The expected life span of the colony is 8 to 12 weeks. The hive should be placed under shade in summer and in the sun in winter and isolated from ants. The hives contain a supplement food for the bees during periods of low abundance of flowers because overvisited flowers may lead to fruits with cork-like spots at the blossom-end.

## Fruit Disorders

Optimal environmental conditions for the crop may not always be possible to reach with no heaters or without a greenhouse structure that ensures good ventilation. Pepper fruits may develop physiological disorders such as “color spots,” cracking, blossom-end rots, and flat-shaped fruits. Most of these disorders are caused by environmental stresses during fruit development but can be minimized by using cultivars that have less susceptibility to stress.

Yellow spots can occur on the outer surface of the fruit (Fig. 10). The “color spots,” sometimes already visible on green fruits, turn yellow as the fruit matures, reducing the visual quality of the fruits for consumers. High incidences of this disorder occurred in summer, and in plants grown at high densities, under shade, or fertilized with high levels of N; avoid pepper varieties susceptible to this disorder.

Fruit cracking results from ruptures on the cuticle at the blossom-end (radial cracking) or all over the fruit surface (russetting) (Fig. 11). Pepper plants which receive too much water can have higher incidences of fruit cracking. Pepper cultivars with thick-walled fruits (>8 mm) are more susceptible to cracking than cultivars with thinner fruit walls.



**Figure 8.** Pepper plants trellised to the 'V' system (left) and in a double row trellised to the 'Spanish' system (right). Credits: Elio Jovicich



**Figure 9.** Use of bumble bees to increase set of high quality fruits. Credits: Elio Jovicich

Flat pepper fruits are caused by low temperature (Fig. 12). Night temperatures of around 64°F ensure an ideal seed set and fruit shape. Low-night temperatures decrease pollen viability in pepper

flowers and modify flower structure making self pollination less effective. Use of bumblebees for pollination can help greatly to improve fruit shape.

Blossom-end rot can be caused by reduced absorption and translocation of calcium into the fruit (Fig 13). Calcium deficiency in the fruit occurs as a result of one or more factors, such as low Ca concentration in the solution or media, excessive salinity in the irrigation solution or media, extreme moisture fluctuations in the media, and rapid plant growth due to high temperatures and solar radiation. The localized deficiency of Ca, which occurs at the sides and lower parts of the pepper fruit, manifest itself as regions with collapsed tissue that gradually turn black, making the fruit unmarketable. Pepper cultivars have different levels of susceptibility to the



**Figure 10.** 'Color spots' in red bell peppers. Credits: Elio Jovicich

plant at each harvest). Sharp pruning scissors or knives should be used to cut the fruits at the level of the abscission zone on the fruits peduncle (Fig. 14). Pepper fruits with intact peduncles are more resistant to bacterial soft rot than those with torn or partial peduncles. Nonmarketable fruits should be removed from the plants as soon as they are observed. However, in the case of fruits with blossom-end rot, some growers advise not to remove young fruits with this disorder as this practice will promote a rapid vegetative growth, which may lead to Ca deficiency in developing fruits, thus increasing the incidence of blossom-end rot.

Marketable fruits are graded by diameter (maximum distance across shoulders). Fruits with greater size bring higher prices. Fruit grades can follow the USDA standards for field-grown peppers or can be based on classifications based on diameter ranges similar to greenhouse peppers imported from



**Figure 11.** Fruit cracking in bell pepper. Radial cracking (left) and russetting (right). Credits: Elio Jovicich

disorder. The disorder in pepper is difficult to prevent with foliar applications of Ca.

### **Harvesting, Packing, and Maintaining Postharvest Fruit Quality**

Throughout the harvest season, pepper plants will have ripened fruits in flushes or waves of production. Under warm environments, ripened fruits can be picked once or twice a week (up to 3 fruits per

Holland (extra-large, diameter >3.3 in; large, 3 to 3.2 in; medium, 2.5 to 2.9 in; and small, 2.2 to 2.4 in). Extra large fruits generally weigh about half a pound, although individual fruit weight will vary with cultivar.

Peppers should not be submerged in water during the transfer to the packing line since water can easily infiltrate the hollow pod and cause postharvest decay. Overhead spray with clean water works well for



**Figure 12.** Bell shaped pepper fruit with abundant seeds (top, right and left) and flat parthenocarpic fruit (bottom, right and left). Credits: Elio Jovicich



**Figure 13.** Blossom-end rot in bell peppers. Credits: Elio Jovicich

washing; free water should be removed prior to packing. Pepper fruits are often individually labeled

and packed in single or double layers in 11-lb corrugated cartons (Fig. 14).

Pepper fruit respiration rate can be reduced to a minimum by lowering the product temperature. Optimal storage conditions are 45°F and 90 to 95% relative humidity. To avoid chilling injury, fruits should not be stored at temperatures below 45°F. Maximum pepper fruit storage life is 2 to 3 weeks under the most favorable conditions. Symptoms of chilling injury are water-soaked spots, pitting, or tissue collapse. Extensive decay develops on chilled peppers when they are removed from low-temperature storage. Temperatures above 55°F enhance ripening and spread of bacterial soft rot.

Rapid cooling of harvested sweet peppers is essential in reducing marketing losses. Pre-cooling by forced-air is the preferred method. Peppers are very susceptible to water loss. Symptoms of shriveling may become evident with as little as 3% weight loss. Pre-cooling and storage in a high relative humidity (90 - 95%) will minimize weight loss. Peppers can be waxed, but only a thin coating should be applied. Waxing provides some surface lubrication which reduces chafing in transit. Water loss can also be limited by packing peppers into cartons with moisture-retentive liners or into perforated polyethylene bags.

### Pests and Diseases

Pests are reduced but not eliminated in screened greenhouse structures. Transplants must be free of pests and weeds must not be present inside the greenhouse. The major arthropod pests observed in greenhouse peppers in Florida are broad mite (*Polyphagotarsonemus latus*), twospotted mite (*Tetranychus urticae*), western flower thrips (*Frankliniella occidentalis*), melon thrips (*Thrips palmi*), green peach aphid (*Myzus persicae*), melon or cotton aphid (*Aphis gossypii*), silverleaf or sweet potato whitefly (*Bemisia argentifolii*), pepper weevil (*Anthonomus eugenii*), fungus gnats (*Bradysia* spp.), and several lepidopterous pests.

Common fungal diseases are powdery mildew (*Leveillula taurica*) and Fusarium (*F. oxysporum* and *F. solani*). For more information on *F. solani* in greenhouse-grown peppers, please refer to this



**Figure 14.** Fruit harvest by cutting at the peduncle's abscission zone (right) and fruits graded, labeled, and packed in 11-lb cartons (right). Credits: Dr. Steve Sargent

UF/IFAS Extension publication, "*Fusarium Stem Rot of Greenhouse Peppers*," at <http://edis.ifas.ufl.edu/CV276>. Western flower thrips can transmit tomato spotted wilt virus (TSWV).

Insecticides are available to control insect and mite pests. However, many chemicals negatively affect bumblebees, beneficial organisms, and the pepper plant itself. Also, crop reentry after using pesticides can complicate management when plants have to be accessed frequently for pruning, training, and harvesting. Some products, such as soaps, oils, and sulfur, often are phytotoxic to pepper plants in the greenhouse.

Research in the Protected Agriculture Project at the University of Florida (<http://www.hos.ufl.edu/ProtectedAg>) and at the Mid-Florida Research & Education Center (<http://mrec.ifas.ufl.edu/lso/>) is evaluating biological control practices used in other regions and crop systems to minimize or avoid the use of pesticides. Augmented biological control involves the release of living organisms that will limit the abundance of other living organisms. In pepper, melon aphids have been successfully controlled by releasing a parasitic wasp, *Aphidius colemani*. Twospotted spider mites were controlled by releasing a predatory mite, *Neoseiulus californicus*. The appearance of

lepidopterous pests is greatly reduced by using insect screens on the greenhouse vents. When adult moths are present in the greenhouse, the larval stages can be controlled by repeated treatments with *Bacillus thuringiensis*. *B. thuringiensis* can also be applied near the base of the plants to control larvae of fungus gnats. Releases of a parasitic wasp, *Eretmocerus eremicus*, were used to maintain low populations of silverleaf whitefly. Current research evaluates using predatory mites *N. californicus* and *Neoseiulus cucumeris* for the control of broad mites. *N. cucumeris* and big-eyed bugs, *Orius spp.*, can be used to control western flower thrips.

Compared to the use of pesticides, with biological control, insects do not develop resistance as they do to certain insecticides. Also, restricted reentry periods to the greenhouse due to the use of insecticides are eliminated, the environment for workers is safer, and harvest products can be labeled "pesticide free," which may attract higher prices and/or increase consumer demand. The use and success of biological control will require that the crop is scouted frequently to determine presence and to estimate population densities of crop damaging pests and their natural or introduced enemies. Combining the use of bumblebees with natural enemies does not present any problems but the use of chemicals may have direct or indirect effects on the bumblebees

and/or natural enemies. Information about the side effects that agricultural chemicals have on bumblebees and on biological control agents can be provided by the companies that supply these organisms.

The production of greenhouse-grown peppers represents an alternative crop in Florida. In the Protected Agriculture Project at the University of Florida, ongoing research on greenhouse-grown peppers on production systems, fruit quality, cultivars, nutrient and water management, integrated pest and disease management, post harvest, and marketing are being evaluated. Current and past research, publications, and links to products used for pepper greenhouse production and other specialty crops are posted in an up-to-date Web site at <http://www.hos.ufl.edu/ProtectedAg>.

**Table 1.** Commercial production schemes of greenhouse-grown bell pepper used in Florida.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<b>Fall to Summer</b>					E			T			H	
<b>Winter to Spring</b>			H			E					T	
<b>Spring to Summer &amp; Fall to Spring (2 crops)</b>	E	T			H		E					
								T			H	
T: Transplant, H: Harvest and E: End of the crop.												