Greenhouse Production in Florida

Florida: A Leading State for Greenhouse Vegetables and Specialty Crops

By George Hochmuth

Florida is the leading state for field production of vegetables, including sweet corn, cucumbers, and snap beans, and second for tomato, pepper, watermelon, and strawberry. The Sunshine State also is a leading producer of greenhouse-grown vegetables (Figures 1 & 2), including herbs, and specialty crops. While some might be surprised to find Florida among the top greenhouse states, there are several reasons for the success of the greenhouse vegetable industry. First, Florida has the mild and subtropical climates that make production in the winter, with low heat inputs, possible. Production in southern Florida is possible with negligible heating costs. Also, much of the year in Florida consists of sunny days, with longer duration than the northern part of the country. Second, Florida is uniquely situated near many major metropolitan areas, in the southeastern US and in Florida itself, that provide ready markets for high quality products. Third, greenhouse production in Florida benefits from a readily available supply of high-quality water and a very good equipment and supply industry. The greenhouse vegetable industry in Florida has grown from 20 to 30 acres in the 1970s to almost 100 acres today. The industry consists of the full spectrum of growers from single greenhouse units to multi-bay operations 10 acres or more in size. The University of Florida – Institute of Food and Agricultural Services (UF-IFAS) has provided continuous support for the greenhouse industry from its research and extension greenhouse facilities in Live Oak and Gainesville. This level of support for a greenhouse vegetable industry is matched nowhere else in the country. This special section of the Citrus and Vegetable Magazine presents some of the information developed by UF-IFAS in support of for greenhouse vegetable industry in Florida. Much more information is available from UF-IFAS and those resources are cited in these articles. Florida has a strong greenhouse vegetable industry and a bright future.

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(Top), Florida Greenhouse tomato , Beli Farms. (Above), Florida greenhouse pepper, Mascot Farms.

Keys to Successful Tomato and Cucumber Production in Perlite Media

By George J. Hochmuth and Robert C. Hochmuth

Tomato and cucumber are popular and important crops for greenhouse production in Florida. Profitability from production of tomato and cucumber requires attention to the many details of crop culture. The major keys to successful greenhouse production of tomato and cucumber are presented in this publication. This guide is directed at the small to medium-sized grower with one to several houses, but much of the information is also useful for larger operations. The information in this guide focuses on tomato (Figure 1) and cucumber (Figure 2), but also applies to other crops grown in soilless media, including pepper, eggplant, melons, lettuce, and cut-flowers. Although this guide focuses on perlite media in lay-flat bags, most of the principles also pertain to other soilless media, such as rockwool slabs and peat-mix bags (Figure 3). In addition, many of these princi-

Figure 1. Greenhouse grown cluster tomatoes ready for harvest.

UF UNIVERSITY of FLORIDA IFAS Extension

Figure 2. European Cucumbers Ready for Harvest.

ples apply to using perlite, pine bark, or similar media in containers, such as nursery containers. More details on each subject are available from the Florida Greenhouse Vegetable Production Handbook (http://edis.ifas.ufl.edu/TOPIC_BOOK_Florida_Greenhouse_Vegetable_Production_Handbook).

What is Perlite?

Perlite is a mined mineral that is crushed, then expanded under high temperature. The crushed material (like kitty litter) expands like popcorn, is cooled, and sieved into various grades based on particle size. Perlite is white in color, very light weight, but has high water holding capacity and high aeration properties (Figure 3).

There are negligible differences in grades of perlite as far as crop performance is concerned. Most crops grow equally well in horticultural grade perlite, coarse or medium size. Perlite is locally available in Florida (e.g., Vero Beach or Jacksonville). Price and sales support might vary among perlite suppliers.

Perlite can be purchased ready to use in pre-made, lay flat bags, approximately three feet long, six to eight inches wide, and four inches tall. Perlite also can be purchased in bulk bags or in medium-sized bags of about four cubic feet. Growers can then purchase rolls of polyethylene sleeving material from greenhouse supply companies and make up their own growing bags. The sleeving material should be black-on-white with black on the inside to minimize light penetration inside the bag.

Reuse of unsterilized perlite is risky. Cost in re-use (handling, sterilization, rewrapping) is significant. High levels of organic matter in reused media might affect the irrigation scheduling program early in season of second crop. Re-used media holds more water because of organic matter (old roots). Old root material might harbor disease organisms from previous crops.

Bag Positioning

In double-row systems, bags are placed on very slight incline toward leachate collection trough (Figure 4). An alternative system uses a single bag from which plants are positioned toward two overhead trellis wires so two rows of plants evolve. In the single-bag system, care should be taken to provide adequate media volume per plant. Both systems have been successfully used in Florida.

Drainage

Small slits should be made in the near bottom of the bags so that excess water will not build up and drown roots. A large reservoir of water in the bag is not required so slits can be positioned to provide nearly complete drainage. A large reservoir maintained in the bag only reduces the volume of aerated root zone, which plants need to grow optimally.

Transplanting

Transplants for the perlite system can be produced in several media types including rockwool, perlite, or vermiculite. The large rockwool growing blocks are not needed in Florida. Care should be taken to completely bury the root media ball of the transplant so that the perlite media in the bag does not wick the moisture from the transplant ball. This is why rockwool growing blocks should not be placed on the surface of the perlite media. Irrigation emitters must immediately be placed in position and directed to wet the perlite nearest the root ball of the transplant. Later on, in a few weeks, the emitter can be moved back a few inches from the transplants.

Cucumbers can be transplanted into growing bags, however, cucumbers also can be seeded directly into the perlite bags. The germination percentage of cucumber seeds is good enough that direct-seeding can result in near 100% stands. Direct-seeding saves considerably on transplant production costs and the challenges associated with production of quality transplants. Growers might wish to start about 5% of their cu-

Figure 3. Various types of growing media.

Figure 4. Lay-flat bags of perlite, newly planting with tomatoes.

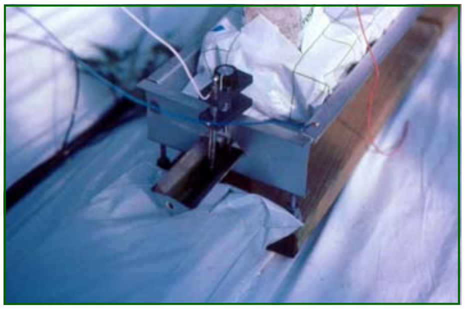

Figure 5. Start-tray and probe controlling off/on cycle of irrigation systems.

Figure 6. Placement of black leachate collection trough and neighboring start-tray.

cumber crop in transplants so that missing direct-seeded plants that fail to emerge and develop can be replaced with a growing transplant.

Irrigation Program

Water Quality. Obtain an analysis of your well water for bicarbonates, pH, iron, sulfur, calcium, and magnesium. Water analysis helps determine problems to be anticipated from emitter clogging (fertilizer precipitation and lime deposits, and bacterial slimes). Plants can use the calcium; knowledge of calcium concentrations can help with fertilizer program. Sometimes, we might want to reduce the amount of calcium nitrate (Ca) if Ca is high in water. Plant leaf analysis should be used to monitor the fertilizer program or to diagnose nutrient deficiencies. For tomatoes, sample the most-recently-matured leaf (about the sixth leaf back from the tip). Sample the whole leaf including the petiole that attaches it to the main stem (just as if removing a leaf for leaning and lowering). Try sap analysis for nitrogen and potassium. Sap squeezed from the petiole of most-recently-matured leaf should read 600 to 1000 ppm nitrate-nitrogen. Ask your local extension agent for help if you are interested in sap testing.

Watering. Irrigation programs for tomatoes growing in perlite can be controlled by the same equipment originally designed for tomatoes in rockwool. The irrigation sequences (number and length) can be controlled by a timer set to operate the irrigation system a set number of times during the day for a predetermined length of time. As long as enough water and nutrients can be supplied to the crop, you will be successful in production. The problem with control by timer is that plants will get water and nutrients whether they need the water or nutrients or not.

Perlite-grown plants can be irrigated by a starter-tray set-up like rockwool (Figure 5). We have had good success using the start-tray and similar management schemes to those for rockwool. Several (40 to 50) small slits are made in the bottom of a perlite bag and the bag formed into the start tray. For more information on irrigation, consult the list of references at the end of this guide.

The approach to fertilizer and water management, with either timer or start-tray, is to apply enough water and enough nutrients at the correct time of crop requirement. Usually we start early in the season with nutrient solutions low (60 to 80 ppm) in N concentrations. Frequent, short irrigations will supply enough total nutrients to the crop. If a timer is used and irrigations are infrequent (once or twice per day), then a more concentrated (100 ppm) nutrient solution might be needed.

Fully grown tomato plants may use two to three pints of water per day in the winter (including that for leaching) and three to five pints on warm spring days.

The key to watering frequency is to balance the amount needed by the crop with the total needed for crop and leach. A general rule-of-thumb is to leach about 10 to 15% at each irrigation event for tomato. Leaching rate for cucumber might need to be 20%. Leaching is needed to minimize salt buildup in the media and to assure all bags are fully wetted with each irrigation event.

Addressing Media-Salt Content

High concentrations of salts in the perlite media can damage plant roots and upset nutrient and water uptake by roots. Tomatoes can tolerate fairly high soluble salt content in the root zone; cucumbers are less tolerant. As water is absorbed by plants, some salts are left behind in the media. These salts are mostly carbonates and sulfates, e.g. calcium sulfate, calcium carbonate (lime), and magnesium carbonate.

If you are applying a nutrient solution with an electrical conductivity (EC) of 1.0 decisiemens/meter, you can tolerate a media EC of 1.5. If you are applying a solution of 2.0 EC (full-grown plants), then you can tolerate a media EC of 2.5 to 2.8. The key is to watch the EC trends and begin corrective measures if it continues to climb. Climbing EC indicates the need to increase frequency of irrigation (more water) by raising the probe setting of the starter tray or increasing the irrigation run time.

Remember, the idea is to balance amount of water needed by the crop with that needed by the crop plus leach. Maintaining the EC of the media slightly above the delivered solution shows that you are a good manager of nutrient solution delivery. A plastic leachate-collection tray (Figure 6) can be used to collect leachate for volumetric measurements and for nutrient analysis.

It is a good idea to have a few milk jugs positioned around the house with an extra emitter punched in.

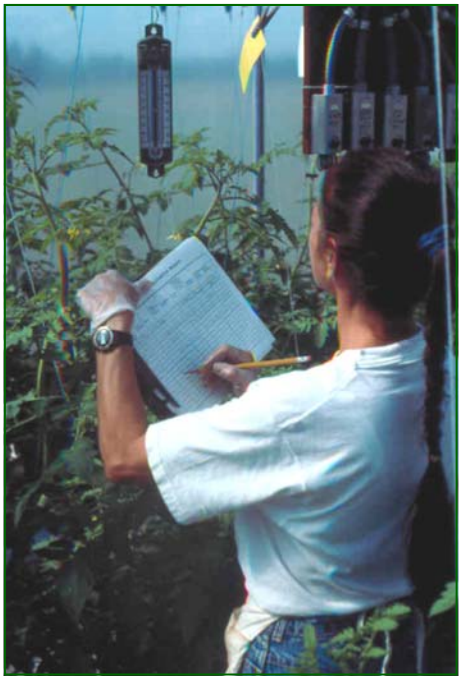

Figure 7. Recording environmental data helps diagnose problems.

Paint the jug black to reduce algae growth and then scratch a clear line from top to bottom of the jug so you can see the solution level. Calibrate the mark by sequentially pouring in pints of water and marking each pint level. The jug helps tell you that the system came on that day and it can tell you how much water was applied.

With experience, you can tell how much solution should be in the jug on a cloudy day versus a sunny day or on a winter day versus a spring day. Several jugs around the house can help you get an idea of emitter flow rate uniformity. You might have problems if variance among emitters is greater than 15%.

Get into the habit of performing the "bag slap test". Pick up the corner of one bag and flop it up and down a couple of times to get the feel for its weight. Check a random six bags per house every day or so. Lightweight bags indicate not enough irrigation or possibly clogged emitters.

Be sure the emitter spaghetti tube length and that of the emitter plugged in for the jug are the same length and size as those for the plants. Otherwise, different flow rate could result. Also, be sure to position opening of emitter, or tube in the milk jug, so that the opening is above the level of the irrigation line in between the rows. Otherwise, siphoning (forward or backward) could result in giving false jug readings.

Check emitter flow rate and uniformity periodically. Use a graduated cylinder or a measuring cup, collect solution as it is delivered for several emitters about the house and check for uniformity. They should be within 10 to 15% of each other. Also, measure flow rate - amount of solution delivered in 15 seconds, for example. This can help determine how long to run the system each cycle. Remember the idea is to achieve about 10 to 15% of leach and to manage the media EC slightly higher than the delivered EC.

It takes time and experience to get all the pieces together. Early season irrigation program is different from full-grown plants. Young seedlings do not have large root systems in the media. Therefore, young seedlings (up to about first blossom) will need to be irrigated on timed basis instead of by the starter tray. Irrigate at least three times a day with enough solution to wet the young root system to encourage roots into the media. After roots become established in the perlite, then control can be switched over to the starter tray.

Starter Trays

Probe Settings. Generally, shallow setting is for frequent irrigations and deeper setting is for less frequent irrigations. Probe setting is one way to adjust the irrigation cycles to achieve the desired leach rate, to achieve the desired amount of water for the plant, and to manage the soluble salt level in the media.

Sometimes, a salt deposit builds up on the probe point. This should be removed regularly as it, in effect, lengthens the probe. Also, algae and bacterial slime might build up in the probe reservoir. Slimes might create a strand from the reservoir to the probe, thus maintaining contact between solution and probe, thus reducing irrigation cycle frequency. Also, roots can grow into the reservoir and should be trimmed back.

Starter tray should be placed in an area of the house representative of the house environment, generally at least 1/4 of the distance from end walls (Figure 6). Place tray in an alley that receives frequent traffic, where it will be observed daily. Many growers do not observe their tray frequently enough.

Good Growers Keep Records

The most consistent and best producing growers are the ones that do good record keeping (Figure 7). Records help diagnose trends and problems during the present season and they are invaluable for helping prevent repeat problems next season.

Important items for regular insertion in the record book are:

1. Max-min temperatures outside and inside.
2. Heating fuel consumption.
3. "Milk jug" measurements.
4. Delivered solution EC, pH, and nutrient solution concentrations, e.g. N and K.
5. Leachate EC and nutrient concentrations.
6. Flow meter readings.
7. Light meter readings.
8. Plant tissue analysis results, e.g. sap readings.
9. Emitter flow rates and uniformity measurements.
10. Fertilizer stock recipes and any adjustments.
11. Volume of leach tank pump out.

"Reading" the Plants

Learn to identify potential problems before they occur. Experienced growers know what healthy plants look like. But, be careful here that you don't associate green, vigorous plants with higher yield. Sometimes overly green, bullish, and thick

Figure 8. Nutrient stock tanks.

plants are not what you want and can actually be an indicator themselves of a problem (too much fertilizer). Overly-vegetative plants are more difficult to manage, more prone to disease, more prone to breakage, and typically have more problems with fruit quality).

Knowing what kind of plant will produce the best fruit with the least trouble is the most important key to being a successful grower. This means that you must devote a portion of each day to being a plant reader and record taker. Write out notes in your record book about what you did today (sort of a diary). You will be glad you did when it comes time to diagnose a problem. Read your book from last year before you start up the new season, and read the old book periodically through the new season to see what the problem was last year and what you did to correct it.

Attention to detail most often sets the good (and profitable) growers apart from the rest. Being observant, recording, and reacting to what you observe are requisites for successful greenhouse vegetable growing.

Irrigation System Design

The irrigation system needs to have all the required parts and in the correct design. You need a backflow prevention system (check valve, pressure relief, and low pressure drain) for systems into which fertilizers are to be proportioned.

Correctly designed systems allow for emitters in the house to have uniform flow rate. All parts should be sized properly.

The system should have pressure regulators and pressure gauges. Also a flow meter would be a good idea to back up milk jug measurements.

Emitters, lines, filters, valves and injectors. The key is emitter orifice size. For Florida water, clogging can be a problem if the emitter orifice is too small. Therefore, it is suggested that the opening to the emitter be at least 0.05 inches in diameter. Options range from pressure compensating "button" emitters to simple "water sticks" that project a stream of solution from spaghetti tubing (0.05 inches inner diameter). It is probably a good idea to have an emitter with a fairly high flow rate to minimize run time of the system and minimize chance of clogging.

Lines should be equipped with flush valves at the end. Open valves every week to flush out collected precipitates that might clog emitters.

All good irrigation systems filter the water delivered to the house. Filtration should be about 200 mesh. Filtering protects the proportioners or injectors from damage, from sand or limestone, from the well, and protects emitters from clogging. Fertilizer from the stock tanks also should be filtered. Also, be sure to use filtered water in the formulation of the fertilizer stocks. Filters should be in black housing to reduce algae growth in the filter. Always check and clean filters regularly; otherwise flow rate of water will be reduced.

Fertilizers are added to the water by injectors or proportioners. Typically proportioners are used in smaller-sized growing operations. Injectors typically are used with systems involving computer control technologies. Proportioners can be used on small-scale operations because they are relatively inexpensive and operate on the water pressure, not requiring electric control.

Both parallel and series installations of proportioners can be used successfully. Proportioners can be installed in parallel to avoid problems associated with pressure losses across serial proportioners. Parallel installation can also be used if more water is needed than the maximum delivery of one proportioner.

Valves installed after each proportioner can be adjusted to equalized suction rates. Keep an eye on stock levels to be sure proportioners are operating equally. Also, check the nitrogen and potassium levels in the emitters to be sure the proportioners are operating correctly. If you have nitrogen and potassium electrode kits, it might be a good idea to have all nitrogen in one stock and all potassium in the other stock (Figure 8). That way you can determine which proportioner is malfunctioning and to what degree, by checking N and K concentrations in the stock tanks.

Injectors are typically used with larger operations in conjunction with computer control. Injectors can be operated by the computer controller to inject various amounts of various fertilizers and chemicals on demand from a computer program.

Back-up Parts. It is always a good idea to have spare parts around, especially for the more important components such as proportioners, solenoid valves, pressure regulators, emitters, filters, etc. It seems as though things break down on weekends, or worse yet, on holidays.

Weather Problems

Media Temperature. We have observed problems with plants such as wilting, iron deficiency, reduced growth, etc., when the media temperature drops below 65ºF. This can happen during extended cloudy and cold periods. Cool temperatures in the root zone reduce water and nutrient uptake. Plants can wilt on a sunny day immediately following a cool, cloudy period. If this is a problem, you might want to consider a bottom or floor heat distribution system to help warm the root area. Also, raising bags up onto benches two or three inches from the floor, so that there is air space, will help insulate media from the cool floor. Media temperature is extremely important for proper plant growth. Temperature sensors and warning or alarm systems are a good investment.

Sunlight. Extended cloudy and cool days might cause too much delay in irrigation cycling. You might need to force the system on for a few cycles on these days. Remember, plants grow slower on these days so they do not need large amounts of nutrients and water, but they do require some.

Leachate Collection

System Design. Environmental concerns will probably dictate that leachate be collected and disposed of properly. Bags should drain into a collection trough and leachate should be removed from the house. Leachate can be collected in a large tank and used to irrigate pasture, garden, vegetable crops, pine trees, nurseries, etc. If the irrigation system is being operated properly, as discussed earlier, then leachate should be relatively low in nutrients but still would represent a potential point-source for pollution, if not disposed of properly.

Computerization

Computerized controllers can be a good investment for some growers; however, electronic controllers are a good investment for all growers. It depends on your size, on how many other functions (besides water and nutrient programs) you want controlled, and on how much information (data) you want collected and stored. Small, one, two, or three-house operations can usually do quite well with simple electronic controllers for their irrigation systems. Larger operations can benefit from the control level and data collection afforded by computerized systems.

Computer-controlled systems collect readings of several environmental variables, e.g. temperature, relative humidity, sunlight intensity, etc. These measurements are analyzed by the computer and decisions are made concerning environmental controls, for example, turning on or off the exhaust fans, deploying shade cloth, or operating the irrigation system. As the computer uses the data it collects to operate the environmental controls, also it stores those data for analysis and reporting to the greenhouse operator.

Pest Control

Greenhouse crops are very good hosts for diseases, insects, and nematodes. Similar problems to what outdoor crop growers' face can occur in greenhouses, and sometimes the problems can be more serious. Greenhouses afford favorable growing conditions for the plant, and the pests also benefit from favorable environmental conditions. The keys to managing greenhouse crop pests fall into several categories: selecting pest resistant varieties (this pertains to diseases), controlling the environment to reduce diseases (Figure 9), constructing the greenhouse to maximize insect exclusion, practicing good sanitation in and around the greenhouse (Figure 10), and applying appropriate chemical or manual control measures. Greenhouses present special challenges for pest control, e.g., rapidly growing crop, tall crops, enclosed growing space (special challenges for worker protection), and mostly manual operations for pest control practices. Therefore, it is critical to stay abreast of preventative measures, rather than to get into situations of crop rescue. More information on pest management is available from the references listed at the end of this guide.

Figure 9. Horizontal air-flow fan for circulating air in greenhouse.

Figure 10. Footbath to sanitize shoes prior to greenhouse entry.

Harvesting and Handling

For maximizing yields and fruit quality, fruits must be harvested at the optimum stage of ripeness. Careful handling and transport from the greenhouse to grading and packing area is very important. Workers must be trained in all aspects of proper harvesting and handling procedures. Fruits for market must be packed in proper boxes which are appropriate for the size of the fruits and properly and attractively labeled

Finishing Up the Season

Clean Up. Media can be dried out near the end of the season by letting plants draw out the water. Just turn off the irrigation system. It will take four to six days for wilting to begin. Remove plants before they become brittle to reduce the mess for the clean up crew. Drying out the bags will make them easier to handle.

Perlite media should be disposed of properly. Although, we have had success using the old media for a second crop, the practice is risky. Perlite can be distributed on a field and incorporated into the soil. Perlite can be used for soil mixes for container production of woody plants.

Irrigation lines and emitters should be cleaned with acid to remove lime deposits and fertilizer precipitates. A 1% acid solution should work in most situations. Acidification should be done at end of season since acidic solutions might injure plants. Flush system following acidification.

Additional Information

More information on hydroponic vegetable production is available from the Cooperative Extension Service of UF/IFAS. The following is a listing of sources for this information.

Visit the North Florida Research and Education Center - Suwannee Valley website at http://nfrec-sv.ifas.ufl.edu.

George J. Hochmuth, Associate Dean for Extension and Robert C. Hochmuth, Multi County Extension Agent, North Florida Research and Education Center – Suwannee Valley, Live Oak, FL 32060

Resources

Florida Greenhouse Vegetable Production Handbook, Vol 1

- Introduction, HS 766
- Financial Considerations, HS767
- Pre-Construction Considerations, HS768
- Crop Production, HS769
- Considerations for Managing Greenhouse Pests, HS770
- Harvest and Handling Considerations, HS771
- Marketing Considerations, HS772
- Summary, HS773

Florida Greenhouse Vegetable Production Handbook, Vol 2

- General Considerations, HS774
- Site Selection, HS775
- Physical Greenhouse Design Considerations, HS776
- Production Systems, HS777
- Greenhouse Environmental Design Considerations, HS778
- Environmental Controls, HS779
- Materials Handling, HS780
- Other Design Information Resources, HS781

Florida Greenhouse Vegetable Production Handbook, Vol 3

Preface, HS783

- General Aspects of Plant Growth, HS784
- Production Systems, HS785
- Irrigation of Greenhouse Vegetables, HS786
- Fertilizer Management for Greenhouse Vegetables, HS787
- Production of Greenhouse Tomatoes, HS788
- Generalized Sequence of Operations for Tomato Culture, HS789
- Greenhouse Cucumber Production, HS790
- Alternative Greenhouse Crops, HS791
- Operational Considerations for Harvest, HS792
- Enterprise Budget and Cash Flow for Greenhouse Tomato Production, HS793
- Vegetable Disease Recognition and Control, HS797
- Vegetable Insect Identification and Control, HS798

Production of Greenhouse-grown Peppers in Florida

By Elio Jovicich, Daniel J. Cantliffe, Steven A. Sargent, and Lance S. Osborne

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 vegeta-

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 southeast Florida where fruits are harvested at the mature green stage. Credits: Elio Jovicich

ble 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.

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^2 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.

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

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.

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

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

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

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 growers 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/PepperCultivars2000.pdf. The red and yellow cultivars produced fruit yields of 1.8 to 2.2 lb per ft^2, the orange cultivars had yields of 1.4 to 2 lb per ft^2 and the chocolate and purple cultivars produced 1.6 lb per ft^2. 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

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

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

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.

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 & 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

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
Fall to Summer					E			T			H	
Winter to Spring			J			E					T	
Spring to Summer & Fall to Spring (2 crops)		T			H		E					
	E							T			H	

T: Transplant, H: Harvest and E: End of the crop.

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

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 "Elephants 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 & 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 ac-

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

tivity 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 over-visited 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 (russeting) (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.

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.

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

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

Harvesting, Packing, & 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 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. Non-marketable 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

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

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 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 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 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 REC (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

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

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, *Eretmocerous 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.

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Alternative Greenhouse Crops

By Robert C. Hochmuth

A significant greenhouse vegetable industry has flourished in Florida for almost 20 years. A statewide survey conducted in 1991 by the University of Florida indicated 66 acres of greenhouse vegetables were produced in Florida. European seedless cucumber (Figure 1) and tomatoes (Figure 2) represented 96% of the total acreage in 1991.

A survey conduced in the same manner in 2001 indicated the total statewide acreage was 95 acres. However, tomato and cucumber represented only one-third of the total acreage in 2001. The leading greenhouse vegetable crop as of 2001 was colored bell pepper. Herb production (primarily basil) had increased to nearly 17 acres which was greater than European seedless cucumber and only slightly less than tomato (18 acres). Lettuce was produced in 7 acres of greenhouses and straw-

Figure 1. Beit Alpha cucumber, several fruit per node.

Figure 2. Cluster tomato production in perlite.

berry in one acre. The complete details of these surveys are available at http://nfrec-sv.ifas.ufl.edu.

In addition, to the "big three" greenhouse vegetable crops; pepper, European seedless cucumber, and tomato, other alternative crops have become very important in North American greenhouses. This is especially evident in Florida and is driven by the unique markets in the Sunshine state.

Large urban centers such as Orlando, Miami, Tampa, Jacksonville, and others provide marketing opportunities for many high value alternative greenhouse crops (Figure 3) for restaurants and specialty ethnic markets. The abundant Florida cruise ship industry also provides a close market for many high value specialty crops. The demand for the highest quality is often difficult to meet by any other production system than greenhouse culture. Several crops, other than the "big three", are being successfully grown and marketed now and others are being evaluated by the University of Florida. A discussion of those crops will follow next.

Mini Cucumber

Mini cucumber (Beit Alpha types) (Figure 1), a smaller version of the standard European seedless cucumber has become a popular new crop. New to the U. S. is the Beit Alpha cucumber, a major cucumber type grown in Israel and exported to Europe. The Beit Alpha cucumber originated in Israel and is now being distributed throughout the world. Beit Alpha cucumbers are hybrids that are gynoecious and parthenocarpic, thus they do not need to be pollinated for fruit development. The fruit is seedless and has a thin skin like the European cultivars, but does not require a plastic shrink wrapping for prevention of dehydration after harvest. This is a major advantage in the cost of post harvest handling and marketing. Fruit production is prolific for Beit Alpha cultivars; many of the small fruits are set on each node and on the laterals. Yields can be compact (10 harvests or less) or continuous (more than 30 harvests), depending on season. Beit Alpha cultivars grow well under extreme environmental conditions, especially high temperature (90° to 95° C). These cucumbers appear to be sensitive to low temperatures (below 50° F) especially in the seedling stage.

Figure 3. Bibb lettuce grown in NFT channels.

Several production and post harvest trials have been conducted by the University of Florida, both in Gainesville and Live Oak, in the past five years. Several cultivars have produced very high marketable yields, equivalent to, or higher than standard European cucumber types. Most Beit Alpha types produce fruits 15 to 20 cm in length and specific size is important in certain ethnic markets. A primary production challenge has been powdery mildew. Most early released cultivars were very susceptible to the disease; however, newer releases appear to have increased tolerance. As many as 18 cultivars are being evaluated by R. Hochmuth this spring at the North Florida Research and Education Center – Suwannee Valley near Live Oak and a dozen others have been evaluated by D. Cantliffe and N. Shaw, Dept. of Horticultural Sciences, Gainesville, FL.

Lettuce and Other Leafy Green Vegetables

The traditional greenhouse lettuce crop in Florida and elsewhere is a bibb heading type grown in NFT channels (Figure 3) or in a floating system (Figure 4). The product is usually sold as a "living plant" with the roots still attached and packaged in a bag or special plastic clam shell. Lettuce is a fast crop, typically taking 30 to 35 days from seeding to harvest. Growing lettuce in the warm season in Florida makes the disorder, leaf tip burn difficult to manage. Environmental controls for temperature and light and cultivar selection are critical to properly managing tip burn. Lettuce acreage in Florida was about 1 acre in 1991, 2 acres in 1996, and 7 acres in 2001. The later increase was mostly due to one large new operation in Central Florida.

Opportunities for greenhouse growers to supply other specialty leafy green vegetable crops is also increasing. Recent educational programs in Northern Florida connected growers with restaurant chefs. These programs revealed great interest among chefs to purchase specialty salad greens. Developing production

Figure 4. Leaf lettuce produced in a small floating system.

Figure 5. Herbs, edible flowers and specialty greens in VertiGro towers.

Figure 6. NFT basil production.

Figure 7. Hydroponic chives in perlite bags.

systems and timing technologies for these markets can be very challenging. Trials at the North Florida Research and Education Center – Suwannee Valley, with vertical systems (Verti-Gro®) for several specialty leafy green vegetables (Figure 5), have been encouraging for growers to meet this challenge.

Herbs

In the last decade, there has been a dramatic increase in greenhouse herb production in Florida, from virtually none in 1991 to nearly 17 acres in 2001. Herbs now rank third in greenhouse food crops, accounting for 18% of the state's greenhouse acreage. The major herb now grown in Florida greenhouses is basil, however, dozens of other herbs are being grown also.

Herbs have a long history of use by humans. In ancient times, as well as today, herbs have been used for medicinal, cosmetic, and culinary purposes. Herb and spice consumption in the U. S. doubled between 1965 and 1985, from 1 to 2 lbs per capita according to a report by S. Stapleton UF, IFAS, NFREC – SV in 2001. The volume of basil and oregano sold in the U. S. increased 187% and 75%, respectively, from 1981 to 1991. Total sales value of fresh-cut herbs produced in U. S. greenhouses was $30,995,000 accounting for nearly 14% of all greenhouse food crops sales in 1998. Fresh-cut herbs accounted for $647,000 in sales of food crops from Florida greenhouses in 1998. The demand for fresh-cut herbs is expected in increase in part due to health-conscious consumers and increasing consumption of ethnic cuisine.

Greenhouse production of herbs offers several market advantages including more rapid plant growth, wintertime production when market prices are highest, and a clean product. The clean, hydroponic product may not require washing prior to shipment, which contributes to a longer shelf-life and a high quality appearance. Quality was rated as the most important factor in selecting herb suppliers by 78% of herb buyers responding to a national survey.

Studies by S. Stapleton and R. Hochmuth were conducted to examine marketable yield of selected fresh-cut herbs from fall through spring in a vertical hydroponic greenhouse production system (Verti-Gro®, Lady Lake, FL) in north central Florida. Herbs included in the trial were: arugula (*Eruca vesicaria*), basil (*Ocimum basilicum*) purple basil (*Ocimum basilicum*), chervil (*Anthriscus cerefolium*), dill (*Anethum graveolens*), lemon balm (*Melissa officinalis*), sweet marjoram (*Origanum majorana*), oregano (*Origanum vulgare*), parsley (*Petroselinum crispum*), Italian (flat leaf) parsley (*Petroselinum crispum*) sage (*Salvia officinalis*), and thyme (*Thymus vulgaris*). The best overall performers in the Verti-Gro® systems have included: basil, oregano, parsley, sweet marjoram, and thyme. Basil is also commonly grown for fresh cut in containers filled with soilless media and also grown for whole-plant sales in NFT systems (Figure 6).

Other successful trials for herb production have included mints and chives (Figure 7) in lay-flat bags filled with perlite. As with most greenhouse specialty crops, growers must become especially knowledgeable about the differences in herb pricing, packaging, post harvest handling, and marketing for success and profit.

\`Galia' Type Muskmelon

\`Galia' muskmelon (*Cucumis melo* L. Reticulatus group) could become another hydroponic crop favorite.

The \`Galia' melon is a green-fleshed muskmelon with a golden-yellow netted rind at maturity. \`Galia' fruits have a unique aroma and sweet flavor, and show promise as a specialty melon. Grown hydroponically in a protected-ag structure, \`Galia' fruit (Figure 8) quality surpasses the quality of field-grown orange muskmelons because of its bold

Figure 8. Greenhouse 'Galia' melons.

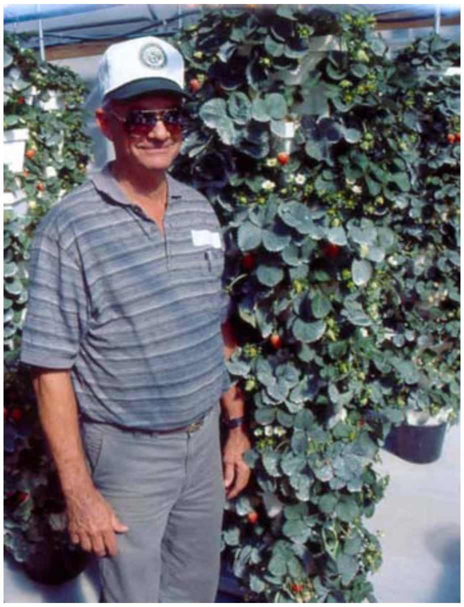

Figure 9. Greenhouse strawberries in VertiGro towers with owner Tim Carpenter.

aroma and high sugar content, leading to higher market value.

The Florida vegetable industry is facing many challenges, including the loss of the soil fumigant methyl bromide in 2005; increased regulations on water, fertilizer, and pesticide use; increased urbanization and loss of production land in southern Florida; challenges from weather, including freezes, wind, and rain; and increased regional and global market competition. Not only are alternative growing methods needed, including protected agriculture in non-traditional growing regions of Florida, but also new specialty commodities, such as \`Galia' melon, may be what Florida growers need to stay competitive. In Europe, \`Galia' melons are in high demand and well known for their superior quality and high soluble solids; furthermore, \`Galia' has become an identifiable trade name.

Research conducted by University of Florida, Protected Ag Project in Gainesville by graduate student, Juan Rodriquez has evaluated several aspects of \`Galia' muskmelon production, including: cultivar selection, nutrient management, soilless

Figure 10. Alternative greenhouse strawberry production system, UF/IFAS Horticultural Sciences Department, Protected Agriculture Center, Gainesville.

media, disease and insect management, pruning methods, and pollination. Disease and insect management can be especially challenging in greenhouse muskmelons grown in Florida. Prices for imported \`Galia" melons have varied from $1 to $3.50 per lb in 1999-2000. Currently this is a very specialized niche market in Florida; however, as production challenges are solved and consumer's acceptance increases, \`Galia' muskmelon may become a popular alternative greenhouse crop in the future.

Strawberry

The Florida greenhouse strawberry (Figure 9) is a product that has captured the imagination of many over the past dozen years. Several aspects of this crop makes the greenhouse concept appealing, including: high fruit values, protection from freezing temperatures, high value in off the season, difficulty with labor harvesting (low crop culture), and challenges of finding suitable alternatives to the soil fumigant, methyl bromide. Even with high interest in greenhouse production of strawberry, commercial adoption remains relatively low in Florida (about one acre). Recent UF research has focused on new production and pest management systems for greenhouse strawberry (Figure 10). High plant populations are required for profits. UF research conducted by Ashwin Paranjpe and Dan

Figure 11. Specialty peppers grown in a greenhouse. Photo: Wanda Laughlin

Cantliffe, Dept. of Horticultural Sciences, indicated plant densities of 17 plants/m^2 is required for break-even yields. Viable systems to accomplish this include vertical systems or moveable trough systems that are suspended above ground level, lending ease of harvest. Plant densities with these systems can be five times greater than the plant densities in typical field culture. Challenges also increase in the greenhouse, however, in the area of pest management, especially for botrytis and spider mites. If these issues are resolved and if problems with soil fumigation and labor in field production persist, greenhouse acreage of strawberry could see rapid increases.

Other Miscellaneous Alternative Crops

As the markets demand highly specialized crops, greenhouse producers may consider meeting these needs. Often the market demands crops in condition or at a timing that

Figure 12. Cut-flower zinnia. Photo: Laurie Osborne

Figure 13. Benary Giant Zinnia
Photo: Laurie Osborne

Figure 14. Lisianthus
Photo: Laurie Osborne

Figure 15. Nasturtium.

can only be met by the utilizing the protection of a greenhouse. Other crops being grown on a small commercial basis in Florida include: fresh-cut flowers, edible flowers, specialty peppers (Figure 11) and tomatoes, and eggplant.

The efforts at the North Florida Research and Educational Center – Suwannee Valley have been successful in refining a production system for cut-flowers similar to that used for vegetables. This project evolved out of interest in greenhouse tomato growers to produce other more profitable greenhouse crops. The crops that have the most potential are those specialty cut flowers that are difficult to ship from other larger production areas. These include flowers such as zinnia (Figure 12 and Figure 13) , snap dragon, sunflower, delphinium, and lisianthus (Figure 14). Small growers in North Florida have been successful in producing top quality flowers for local sales. Expansion of these local marketing efforts depends upon growers being able to grow several different species to maximize the number of specialty cuts to be sold on a weekly basis. In addition, flowers that continue to branch and produce more cuts on the same plant over a long period of time have shown to be the most profitable candidates. Zinnia and snap dragon, for instance, have this type of growth habit.

Edible flowers can be good companion crops for local greenhouse producers, especially herb producers. Although the demand is small, the value is high and the opportunity to provide high quality edible flowers to chefs in urban Florida restaurants is great. Vertical production (Verti-Gro®) of these has been highly successful in trials at the North Florida Research & Education Center – Suwannee Valley. Edible varieties of nasturtium (Figure 15), viola, stock, and marigold have all been successfully produced in trials at Live Oak.

Specialty varieties of pepper, tomato, and eggplant also can provide alternative crop opportunities for greenhouse growers, especially for local markets. In some cases, production of specialized varieties of many crops in the field can be very difficult due to diseases, insects, or weather problems. The greenhouse may create opportunities to produce highly specialized crops, like heirloom tomatoes, off season specialty pepper or tender eggplant varieties. These are typically opportunities for small and specialized greenhouse operations. Many small operations have been successful with this diversification approach by selling directly to consumers at Farmers Markets or other retail markets. High quality greenhouse tomato, cucumber, or pepper accompanied with lettuce, cut flowers, strawberries, herbs, and specialty leafy green vegetables can make a great crop mix at a local market for a small, but talented greenhouse grower.

For more information on protected agriculture visit:

http://www.hos.ufl.edu/ProtectedAg/

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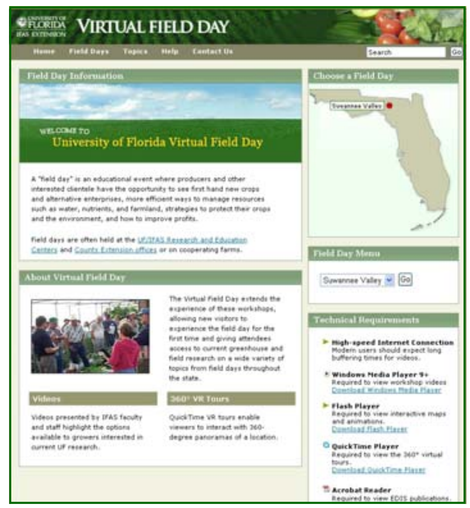

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