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Greenhouse-grown Colored Peppers: A Profitable Alternative for Vegetable Production in Florida?

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Summary. The increase in U.S. demand for colored bell peppers (*Capsicum annuum*) has been satisfied with increased supplies from imports and increased domestic production. Greenhouse-grown peppers of red, orange, and yellow colors were imported during the period 1993–2002 at wholesale fruit market prices that were three to five times greater than field-grown fruits. With high market prices and a suitable environment for growing colored peppers under inexpensive greenhouse structures [<$40/m² ($3.7/ft²)], up to 14 ha (34.6 acres) of greenhouses produced bell peppers in Florida in the year 2002. To estimate the profitability of a bell pepper greenhouse enterprise, a budget analysis was used to calculate the returns to capital and management. Production costs of greenhouse-grown peppers were estimated assuming the use of current technology applied in commercial greenhouse crops in Florida and in experimental crops at the University of Florida. Production assumptions included a crop of nonpruned plants grown in soilless media in a high-roof polyethylene-covered greenhouse [0.78 ha (1.927 acres)] located in north-central Florida. For a fruit yield of 13 kg·m^{-2} (2.7 lb/ft²), the total cost of production was $41.09/m² ($3.82/ft²), the estimated return was $17.89/m² ($1.66/ft²), and the return over investment was 17.1%. A sensitivity analysis indicated that fruit yields should be greater than 7.8 kg·m^{-2} (1.60 lb/ft²) in order to generate positive returns based on a season average wholesale fruit price of $5.29/kg ($2.40/lb). For this price, a range of possible fruit yields [5–17 kg·m^{-2} (1.0–3.5 lb/ft²)] led to returns ranging from –$9.52 to 30.84/m² (–$0.88 to 2.87/ft²), respectively. The estimates indicate that production of greenhouse-grown peppers could represent a viable vegetable production alternative for Florida growers.

Outside the U.S., colored pepper fruits are extensively produced in greenhouses (Costa and Heuvelink, 2000; Morgan and Lennard, 2000; Nuez et al., 1996; Resh, 1996). Spain, The Netherlands, Canada, Israel, and Mexico have large greenhouse areas dedicated to the production of colored pepper fruits which are shipped to many countries throughout the world, including the U.S. (Table 1). Greenhouse production of peppers in the U.S. is minimal; we estimate that the area in 2002 was approximately 50 ha (123.5 acres). In 1998, 165 greenhouse operations (14 ha) in the U.S. were dedicated to growing peppers with a total wholesale value of $4.8 million (U.S. Dept. of Agriculture, 1998). In the present report we describe a greenhouse system for peppers, review historical prices, and investigate the potential for production of colored bell peppers as a viable vegetable production alternative for Florida growers.

Greenhouses for production of vegetables in Florida. In Florida, although vegetables are mostly pro-

Table 1. Area with greenhouse-grown bell peppers in selected countries that export colored fruits to the U.S. and area with greenhouse-grown peppers in the U.S.

Country	Area (ha)[z]	Source
Mexico	165	J.Z. Castellanos, personal communication
Canada	144	Agriculture and Agri-food Canada, 2003
Netherlands	1,200	Valero-García, 2003
Israel[y]	535	P. Imas, personal communication
Spain	10,000	Sánchez et al., 2000; Valero-García, 2003
U.S.[x]	14	U.S. Dept. of Agriculture, 1998

[z]1.0 ha = 2.47 acres.
[y]Includes high tunnels.
[x]An estimate for 2002 would be near 50 ha.

duced in the open field, a few growers have been using greenhouses to produce high value vegetable crops [such as colored peppers, Beit Alpha and Dutch types of cucumbers (*Cucumis sativus*), and beefsteak and cluster types of tomatoes (*Lycopersicum esculentum*)] that are difficult to produce outdoors (Tyson et al., 2001). The area of greenhouses dedicated to vegetable production in Florida was nearly 31.8 ha (78.58 acres) in the year 2000 (Tyson et al., 2001).

PEPPER IMPORTS TO THE U.S. Consumption and imports of fresh-market bell peppers to the U.S. have been increasing over the past 10 years (U.S. Dept. of Agriculture, 2001). From the years 1992 to 2002, the total domestic use of bell peppers increased from 657,710 t (724,989 tons) to 903,747 t (996,194 tons) (U.S. Dept. of Agriculture, 2003a) and the annual per capita fruit consumption increased from 2.6 kg (5.73 lb) to 3.2 kg (7.05 lb), respectively (U.S. Dept. of Agriculture, 2003b). The U.S. Dept. of Agriculture (2001) reported that 24% of Americans consume at least one food containing bell peppers daily, and that 10% of these consumers use fresh bell peppers.

In the U.S., colored bell pepper fruits are considered specialty commodities (U.S. Dept. of Agriculture, 2001). For a growing segment of pepper consumers, the demand for colored fruits has increased despite having two or more times higher prices than mature green fruits at retail supermarkets (Frank et al., 2001; U.S. Dept. of Agriculture, 2001). Countries that produce colored peppers have taken advantage of this market opportunity and have been exporting colored peppers to the U.S. (Cantliffe and VanSickle, 2001; Fintrac, 2003; Lopez and Shwedel, 2001; U.S. Dept. of Agriculture, 2001) (Fig. 1). Countries that shipped only high quality colored fruits attracted high annual average price values per unit weight of pepper [>$1.50/kg ($0.68/lb)] (Fig. 1). In 2002, 26.9% of the volume of the bell peppers consumed in the U.S. was imported for a value of $290.6 million (40.6% of the total value of bell peppers sold in the U.S.), and 98.9% of this value corresponded to shipments from Mexico (green and colored fruits shipped throughout the year, mostly in the period November–May), Canada (green and colored fruits shipped in the period

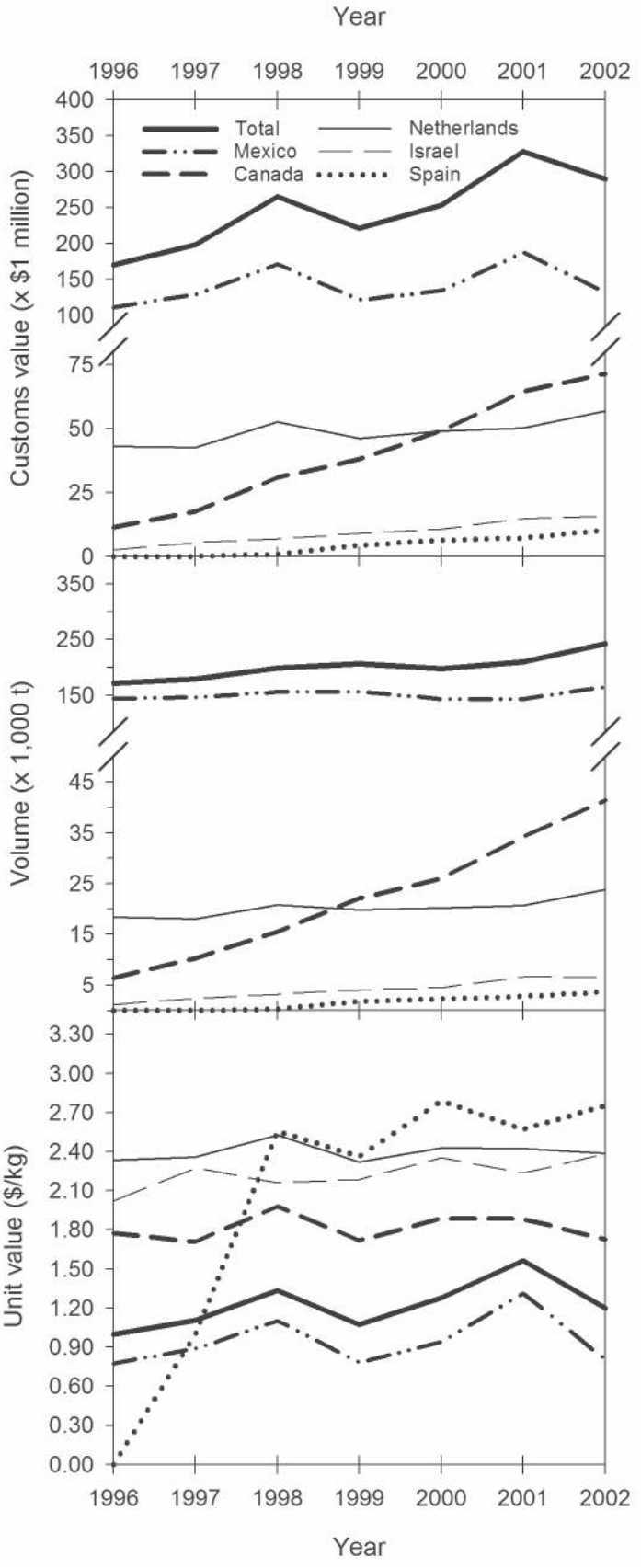

Fig. 1. Total value, volume, and unit value of bell pepper fruits (all colors) imported into the U.S. from major shipping countries throughout the years 1996–2002 (U.S. Dept. of Agriculture, 2004); 1.0 t = 1.10 tons; $1.00/kg = $0.454/lb.

March–January), The Netherlands (colored fruits shipped in the period February–December), Israel (colored fruits shipped October–April), and Spain (colored fruits shipped in the period October–April) (Table 2) (U.S. Dept. of Agriculture, 2002, 2003a, 2003c). Sales from Canada, Israel, and Spain have increased in the recent years, with more colored fruits being shipped. Greenhouse area dedicated to peppers has been increasing in Mexico and their sales of high quality colored peppers in the U.S. have increased (Cantliffe and VanSickle, 2003). The fluctuations of sales in the U.S. from countries shipping bell peppers (U.S. Dept. of Agriculture, 2003a) are shown in Fig. 2.

Field production of bell pepper in Florida. Florida is the main U.S. winter supplier of bell pepper fruits to the northern and midwestern states because it benefits from a mild winter climate in the central and southern part of the peninsula (Florida Agriculture Statistics Service, 2003). About 7163.1 ha (17,700 acres) of bell peppers were harvested in the period Aug. 2002 to July 2003 in Florida (Florida Agriculture Statistics Service, 2003). Pepper crops are grown on polyethylene-mulched beds, fumigated with methyl bromide, and irrigated through subsurface or drip irrigation systems (Maynard and Olson, 2003). Fruits are harvested weekly during a period of approximately 1 month and almost exclusively picked at the mature green stage. Although field growers receive a premium price for mature ripened peppers, the production of red, orange, or yellow peppers represents a higher risk in harvesting satisfactory quality and adequate yield as compared with premature harvests of green peppers. In pepper plants, development of full color in fruits is completed 2 to 3 weeks after they reach the mature green stage (Rylski, 1986). The length of the period of full color development (green to full color) depends on environmental conditions.

Table 2. Volumes, values, and origins of bell peppers imported into the U.S., and volumes and values of the production, exports, and use of bell peppers in the U.S. in the year 2002.

Country	Volume (t)[z]	Volume (%)	Value ($1000)	Value (%)	Unit value ($/kg)[y]
Mexico[x]	164,724	67.8	132,727	45.7	0.81
Canada[w]	41,414	17.1	71,417	24.6	1.72
Netherlands[v]	23,852	9.8	56,844	19.6	2.38
Israel[v]	6,563	2.7	15,638	5.4	2.38
Spain[v]	3,694	1.5	10,161	3.5	2.75
Dominican Republic[x]	1,787	0.7	1,753	0.6	0.98
Belgium[v]	267	0.1	623	0.2	2.33
Others	577	0.2	1,427	0.5	2.47
Total imports	242,876	100.0	290,589	100.0	1.20
U.S. production[x]	734,118	---	498,650	---	0.68
U.S. exports	73,247	---	73,421	---	---
U.S. domestic use	903,747	---	715,818	---	---

[z]1.0 t = 1.10 ton. Volume and price data obtained from the U.S. Dept. of Agriculture (2002, 2003a, 2003c).
[y]$1.00/kg = $0.454/lb.
[x]Mostly field-grown green fruits and some colored fruits.
[w]Field-grown green fruits and greenhouse-grown colored fruits.
[v]Greenhouse-grown colored fruits.

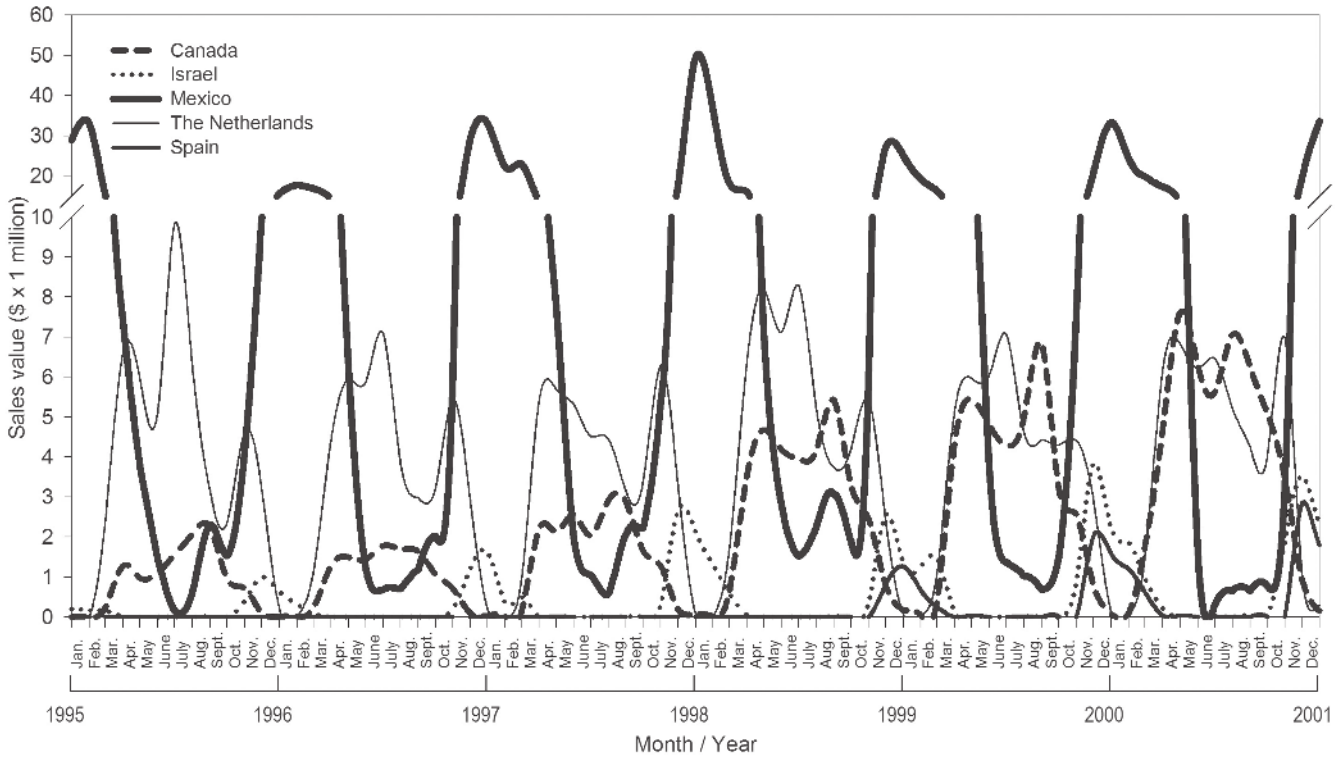

Fig. 2. Total sales value of bell peppers imported to the U.S. from selected countries throughout the years 1995–2001 (U.S. Dept. of Agriculture, 2003a).

During the ripening period, pepper fruits in the field are often exposed to adverse environmental factors such as rainfall, extreme air temperatures and solar radiation, and insect pests and diseases, which significantly reduce fruit quality and marketable yield. High solar radiation, temperature and humidity characterize Florida's weather during the late spring and summer (Bureau of Economic and Business Research, 2000; Winsberg, 1990). In central and north Florida, and occasionally in some southern areas of the peninsula, night temperatures can fall below 0 °C (32.0 °F) during the late fall and winter. Therefore, extending the crop period to harvest full-color fruits is generally not practical in open-field pepper production, although in the warmer coastal areas of southern Florida, some growers harvest full-color pepper fruits from a portion of their crop. This practice can increase income but also increases the risk of decreased fruit yield and quality (VanSickle, 2003).

Research and greenhouse production of bell pepper in Florida. In the past 5 years, the Protected Agriculture Project, Horticultural Sciences Dept., University of Florida, Gainesville (lat. 29°39′N, long. 82°19′W) evaluated the production of bell pepper as an alternative crop for local growers and reported promising fruit yields and high fruit quality during extended growing seasons in north-central Florida using technologies adapted for regions with subtropical and mild winter climates (Cantliffe, 1999; Jovicich, 2001; Shaw and Cantliffe, 2002). Fruit yields were higher than field-grown bell peppers, comparable or higher than average yields of greenhouse-grown peppers in Spain and Israel, but lower than greenhouse-grown peppers in Canada and The Netherlands (Table 3). In 1998, there were eight greenhouse operations in Florida growing bell peppers for a total of 9.51 ha (23.5 acres) (U.S. Dept. of Agriculture, 1998). Fruit yields per unit area in Florida greenhouses were twice as high as field-grown pepper yields in 1998; moreover, because of the type and quality of the commodity, colored fruits from the greenhouses had sales values 11 times greater than that of field-grown peppers (Table 4). In the year 2001, bell pepper had the largest area in production among vegetables produced in greenhouses in Florida [pepper, tomato, cucumber, and lettuce (*Lactuca sativa*)] (Tyson et al., 2001). In 2003, the area with greenhouse-grown bell peppers in Florida was estimated to be 14 ha (34.6 acres), consisting of half a dozen growers with greenhouse areas that ranged from <1 to 8 ha (2.5 to 19.8 acres), and located in central and southern Florida.

Table 3. Yields of bell pepper fruits produced in greenhouses, and in field crops in Florida.

	Marketable yield[z]			
	($t \cdot ha^{-1}$)	($kg \cdot m^{-2}$)	(kg/plant)	Source
		Greenhouse crops		
The Netherlands[y]	260	26	8.7	Costa and Heuvelink, 2000
Canada[y]	220–260	22–26	7.3–8.7	Mirza, 2003
Israel[x]	70–140	7–14	2.3–4.7	P. Imas, personal communication
Spain (Almería)[w]	60–70	6–7	2–2.3	Costa and Heuvelink, 2000
U.S. (Florida)[v]	70–150	7–15	2.3–5	Jovicich, 2001; Shaw and Cantliffe, 2002
		Field crops		
U.S. (Florida)[u]	28.5	2.9	0.66	Maynard and Olson, 2003

[z]Approximate plant density in greenhouses is 30,000 plants/ha (12,141 plants/acre), while in Florida field crops it is 43,242 plants/ha (17,500 plants/acre); 1.0 $t \cdot ha^{-1}$ = 0.45 ton/acre; 1.0 $kg \cdot m^{-2}$ = 0.21 lb/ft²; 1.0 kg/plant = 2.20 lb/plant.
[y]In The Netherlands, plants grown in soilless media, in glasshouses with climate control, including injection of carbon dioxide. Similar production systems are used in Canada.
[x]In Israel, yields in high plastic tunnels and unheated greenhouses are 7–10 $kg \cdot m^{-2}$ (1.4–2.0 lb/ft²). In heated greenhouses, average yields are 14 $kg \cdot m^{-2}$ (2.9 lb/ft²).
[w]In Spain (Almería), plants grown in sand, in low-roof low-cost greenhouse structures with no climate control.
[v]Marketable fruit yields of colored peppers obtained in commercial crops and Univ. of Florida experimental crops over the past 5 years. Plants grown in soilless media and mostly in passively ventilated high-roof greenhouse structures covered with polyethylene, some of them with supplemental fuel-heating during winter months.
[u]Ten-year (1992–2002) state average of mostly green peppers [33,015.2 $kg \cdot ha^{-1}$ (1052 bu/acre at 28 lb/bu)] (Maynard and Olson, 2003). Two rows per bed and 1.80 m (5.9 ft) between centers of the rows. Yields for colored peppers grown in the field are lower. Yield data are not available for color peppers grown under field conditions in Florida.

Table 4. Total harvested area, production, yield, and dollar values for field-grown bell peppers and greenhouse-grown peppers (season 1997–98) in Florida.

Production and value	Field[z]	Greenhouse[y]
Area (ha)[x]	7611	9.5
Production (t)[w]	256,337	750[v]
Yield ($t \cdot ha^{-1}$)	33.7	78.9
Value		
Fruit price ($/kg)[u]	1.08	5.09[t]
Total (million $)	276.2	3.8
Avg per ha ($/ha)[s]	36,294	401,684

[z]Crop season 1997–98; mostly green peppers (Florida Dept. of Agriculture and Consumer Service, 2002). Annual average fruit price calculated from total value divided by total production.
[y]Colored bell peppers produced in 1998 (U.S. Dept. of Agriculture, 1998). Area in the year 2003 was 14 ha (34.6 acres).
[x]1.0 ha = 2.47 acres.
[w]1.0 $t \cdot ha^{-1}$ = 0.45 ton/acre.
[v]Total production and average fruit yield in the total greenhouse area were estimated using the average fruit price for colored peppers in 1998 and total wholesale value and production area reported by the U.S. Dept. of Agriculture (1998).
[u]$1.00/kg = $0.454/lb.
[t]Wholesale price at the Miami terminal market, during the harvest period Nov. 1997–May 1998.
[s]$1.00/ha = $0.405/acre.

Most of the technology and management practices applied to greenhouse pepper crops in Florida have been introduced from Canada and The Netherlands. This includes management of nutrients delivered through drip irrigation and plant pruning systems to two stems, with plants' stems trained vertically onto hanging twines (Portree, 1996; Resh, 1996). However, pepper greenhouse production in Florida can benefit from greenhouse technologies generated in countries with comparable mild winter climates. Compared to the highly intensive systems used in northern latitudes, some of the low-cost technologies used in mild winter climates (Costa and Heuvelink, 2000; Martínez, 1999; Nuez et al., 1996) perform well in Florida (Cantliffe, 1999; Jovicich, 2001; Jovicich et al., 2004).

High-roof, passively ventilated greenhouses represent a functional and low-cost structure for subtropical and tropical regions (Wittwer and Castilla, 1995). Shading and large screened openings in these high structures [about 5 m (16.4 ft) distance from the

Table 5. Structure dimensions of one of the two identical greenhouse units, and pepper plant arrangement used in the enterprise budget analysis.

Structure dimensions and plant arrangement	One greenhouse unit
Structure dimensions	
Gutter base height (m)[z]	4
Front width (m)	70
Total no. of bays (no.)	10
Width of each bay (m)	6.40
Side length (m)	56
Length of each bay (m)	52
All-around distance from sides (m)	2
Area of a bay [6.40 × 52-m] (m^2)	333
Total area [70 × 56-m] (m^2)	3920[y]
Growing area [64 × 52-m] (m^2)	3328[y]
Plant arrangement	
Distance between plant rows (m)	1.28
Within-row plant spacing (m)	0.25
Plant rows/bay (no.)	5
Plants/row (no.)	208
Plants/bay (no.)	1040
Plant density in the growing area (no./m^2)	3.13
Total no. of plants (no.)	10,400[x]

[z]1.0 m = 3.28 ft.
[y]The total floor area for the two greenhouse units was 7840 m^2 (84,392 ft^2) [equivalent to 0.78 ha (1.927 acre)], and the total crop growing area was 6656 m^2 (71,647 ft^2) [equivalent to o.67 ha (1.656 acre)].
[x]The total number of plants in the two units was 20,800.

floor to the gutter] facilitate ventilation and lowering of air temperatures during periods of warm weather (Monteiro, 1994; Wittwer and Castilla, 1995). In central and southern Florida, little fuel is needed for warming the crop during winter. Greenhouse pepper crops in Florida are not grown in soil in order to avoid nematode and soilborn diseases. In the greenhouse, as an alternative to soil and to the use of chemical disinfection, pepper plants are grown in containers with soilless media, which can be reused for several crops as long as no disease contamination of the substrate occurs. The plants are irrigated through drip irrigation, which allows controlling the amounts of nutrients and water.

Returns of greenhouse-grown peppers. Greenhouse area is predicted to expand in the near future, in part as a consequence of the greater demand for specialty vegetable crops, loss of methyl bromide, and an increase in urban sprawl and price of arable land (Cantliffe et al., 1999). In Florida, production costs and returns have been estimated for tomatoes grown in small greenhouses [with a floor area of around 278.7 m^2 (3000 ft^2)] (Hochmuth and Belibasis, 1991; Smith, et al., 2003). However, no information about potential profitability has been published for peppers grown in Florida's greenhouses. The objective of this report is to estimate the potential profitability of a greenhouse enterprise producing mature-ripened bell peppers in Florida. The analyses have the purpose of providing information that will assist growers and agricultural investors in evaluating greenhouse pepper production as a potential business opportunity in Florida.

Methods

The origin of the data used in this economic analysis was from both experiments at the Protected Agriculture Center (Cantliffe, 1999) and from commercial growers. A typical bell pepper production cycle was assumed for a greenhouse area of 0.78 ha, approximately the smallest size existing in the state.

Greenhouse structure. Two identical greenhouse units with a total structure floor area of 7840 m^2 (1.94 acre) and with a crop growing area of 6,656 m^2 (1.64 acre) were assumed in the enterprise budget analysis (Table 5). The multiple-bay high-roof greenhouse structures (commercially available and used by local growers) were covered with polyethylene and had retractable side walls and saw-tooth roofs with a roof-vent on every bay (Fig. 3). All openings were screened with a 50-mesh insect-proof screen. Since the greenhouses were located in north-central Florida, minimal heating (restricted to nights and early mornings) was necessary from the end of November to the beginning of March in order to have a good plant growth with high quality fruits. Occasional nighttime heating was needed during April and May. Diesel-fueled heaters with convection tubes laid on the greenhouse floor were used in conjunction with aluminized thermal screens to successfully keep minimum temperatures above 13 °C (55.4 °F) with a low use of fuel. Sidewall openings, fans, and aluminized screens were used to reduce temperatures during the beginning and end of the growing season. During August and from March to May, air could be blown through the same heater's convection tubes to improve the ventilation from that of the natural passive ventilation provided by the greenhouse structures.

Fig. 3. Passively ventilated greenhouses at the Protected Agriculture Center in Gainesville, Fla. The greenhouse units used in the budget analysis presented in this report were similar but with a larger area.

CROP CYCLE. The pepper crop used as the basis of this budget analysis lasted 298 d from seeding to the removal of the crop. Pepper seedlings were grown in plug trays for 35 d and then transplanted at the beginning of August. Vertical trellising of the plants, scouting plants (for pests, diseases, beneficial arthropods, and bumble bee activity), and monitoring the volumes of water and levels of nutrients supplied with irrigation were the main labor activities until the end of October. Harvesting of ripened fruits started at the end of October and continued during 28 weeks (usually one harvest per week, with a total of 30 harvests), until the end of May.

PLANT PRODUCTION SYSTEM. Plants were trellised to the "Spanish" system. In this trellis system, plants are supported vertically by twines extended along the rows and on both sides of the canopies [up to six levels of twines in 1.8-m-tall (5.91 ft) plants] and by vertical poles (Fig. 4). With the "Spanish" trellis system, minimal pruning is done to the plant canopy. Therefore, the amount of labor needed is about 25% of the labor needed with the "V" trellis system, another system where plants are regularly pruned to form two stems and where each stem is vertically supported with individual strings that are wound around the stems (Jovicich, 2001). In Florida, fruit yield and quality have been similar in both trellis systems (Jovicich and Cantliffe, 2001; Jovicich et al., 2004). Plants were grown in 11.4-L (3 gal) nursery pots containing perlite and drip-irrigated with a solution of water and nutrients (Hochmuth, 1997; Jovicich, 2001). The frequency and duration of the irrigation events were controlled by an automated system. The volumes of irrigation solution and levels of nutrients were changed with plant growth, air temperature, and solar radiation levels. Each plant received a total 240 L (63.4 gal) of water and 480 g (16.9 oz) of fertilizers that included macro and micronutrients.

POLLINATORS, PESTS, AND DISEASES. Bumblebees (*Bombus impatiens*) were required to aid natural pollination, and thus to improve fruit set and fruit quality. The crop was scouted weekly for pest and diseases, and beneficial insects, and to check on the activity of the bumblebees. Pest control combined the use of biological and chemical control measures. Biological control of insect pests included the use of *Bacillus thuringiensis* [for control of fungus gnats (*Bradysia* spp.)], and releases of parasitoid *Aphidius colemani* [for control of cotton aphid (*Aphis gossypii*) and green peach aphid (*Myzus persicae*)] and of the predatory mite *Neoseiulus californicus* [for control of two-spotted spider mite (*Tetranychus urticae*) and broad mite (*Polyphagotarsonemus latus*)]. Miticides for broad mite control were used only if severe infestations occurred and applications were restricted to the affected areas of the crop. Other pests that may have been present [e.g., pepper weevil (*Anthonomus eugenii*), silverleaf whitefly (*Bemisia argentifolii*), and western flower thrips (*Frankliniella occidentalis*)] would have required other specific predators and/or pesticides. Starting in January, preventive fungicide applications were used to control powdery mildew (*Leveillula taurica*).

FRUIT YIELDS. Fruit yields of bell pepper hybrids, with red, orange, or yellow color were estimated from those obtained in experimental crops in north-central Florida [7–14 kg·m^{-2} (1.4–2.9 lb/ft^2)] (Jovicich, 2001; Shaw and Cantliffe, 2001; U.S. Dept. of Agriculture, 1998) and in commercial crops in central and southern Florida, where growers currently obtain a similar yield range (Table 3). After harvesting, marketable fruits were graded by size, labeled and packed into 5-kg (11.0 lb) cartons, and then stored in a refrigerated room at 7 °C (44.6 °F) and 95% relative humidity (Jovicich et al., 2003). Cull fruits, such as those with blossom-end rot, cracking, or those unshaped, were detached from the plants during the harvest operations.

PEPPER FRUIT PRICES. Historical

Fig. 4. Pepper plants grown in 11.4-L (3 gal) containers and trellised to the "Spanish" system in a passively ventilated greenhouse at the Protected Agriculture Center in Gainesville, Fla.

market prices for mature ripened peppers were estimated from market prices of imported peppers supplied by The Netherlands, Spain, and Israel, which have been shipping only greenhouse-grown bell pepper fruits to the U.S. Wholesale price values at the Miami terminal market were obtained from U.S. Department of Agriculture data, available in the "Wholesale Market Vegetable Report" from the Market Information Database System of the Food and Resource Economics Dept., Univ. of Florida (VanSickle, 2004). Monthly average bell pepper wholesale prices (unadjusted for inflation) were calculated from maximum and minimum price values in transactions carried out on Thursdays from Dec. 1993 to Jan. 2002. Means and standard deviations were calculated for selected price series and are reported as "mean price value ± SD." Prices of fruits were differentiated by fruit origin, size, and color, and by weight of the packed carton. Prices are presented in units of dollars per kilogram, or the equivalent of dollars per 5-kg carton.

Monthly average prices were estimated for mature green bell peppers, combining imports (mostly from Mexico) and U.S. production. Average prices for mature-ripened fruits produced in the field were calculated from shipment data for major bell pepper production states (Florida, California, North Carolina, and Georgia). Countries such as The Netherlands, Spain, and Israel export to the U.S. only mature-ripened bell pepper fruits from greenhouse-grown crops; thus, average prices for fruits arriving from these three countries combined were used to estimate prices for fruits produced in greenhouses. Field peppers are primarily packaged in 12.7-kg (28 lb) cartons (1-1/9 bu), while greenhouse-grown fruits are packaged in 5-kg cartons.

Budget analysis. An enterprise budget that consisted of gross revenue, costs, and profit associated with the production of bell peppers in a greenhouse was used to estimate annual profitability. Methodology described by Kay and Edwards (1994) for a budget analysis was adapted for greenhouse production. The budget tables included items, quantities, units, and prices used throughout a typical production cycle in north-central Florida.

Gross revenue was estimated by multiplying the wholesale market price by the marketable fruit yield. Average monthly prices of greenhouse-grown pepper fruits were multiplied by monthly fruit yields during the November–May harvest period and summed to obtain the total gross revenue expressed in dollars per unit area of total greenhouse floor area (Table 6). The total fruit yield was estimated to be 13 kg·m^{-2} based on the technology and practices used, and on the length of the crop season. Fruit yield was expressed in weight units per unit of usable area (85% of the total greenhouse floor area), whereas costs and revenues were based on a unit area of the total greenhouse area (0.78 ha). The formula used to calculate gross revenue was: gross revenue ($/unit or total area) = yield (weight per unit or total growing area) × 0.85 × market price ($/unit weight).

Total costs were divided into fixed and variable costs. Total fixed costs included depreciation of durables and expenses that would still exist even when no crop was grown in the greenhouse. A summary of the items considered in the total investment, with their original costs, expected life, and depreciation is presented in Table 7. The costs of the greenhouse structure, irrigation equipment, and all other material inputs required for the production of the crop were calculated using estimates from manufacturing companies. Annual depreciation of long-term items was based on a zero salvage value and an estimated useful life in years (Table 7). Land price was not included in the investment. Other fixed costs included were those incurred from repairs and maintenance, taxes and licenses, insurances, telephone, and office expenses (Table 8).

Variable or operating costs were those that would be incurred only if the crop was grown. Variable costs were divided into preharvest, harvest, packing and marketing costs, and sales transaction costs. Quantity and prices of inputs were obtained by contacting input suppliers. The list of activities and inputs throughout the crop production cycle are summarized in Table 9. Records for types and amounts of labor needed in a pepper production cycle were estimated from experimental and commercial crops. Employee wages ranged from $6.50 (basic) to $15.00 (specialized) per hour depending on the expertise needed for a specific task. An additional cost of 20% of the wage value was estimated for contributions to social security and insurance, unemployment tax, and other employee expenses. The sales transaction cost was estimated to be 15% of the gross market price. Total cost per unit area was the sum of variable costs and fixed costs.

Table 6. Monthly marketable fruit yields, average wholesale market prices, and gross revenues in a typical fall to spring greenhouse-grown bell pepper crop in Florida with a total estimated yield of 13 kg·m^{-2} (2.7 lb/ft^2).

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Nov.–May
Yield[z] (kg·m^{-2})	T[y]			1.0	3.0	1.5	2.0	2.0	2.5	1.0	End		13
Price[x] ($/kg)	3.76	4.09	3.98	4.58	5.28	5.63	4.75	5.30	6.00	5.50	4.68	4.09	5.29[w]
Gross revenue[v] ($/m^2)				4.58	15.84	8.45	9.50	10.60	15.00	5.50			69.47[u]
Gross revenue ($/0.78 ha)				30,484	105,431	56,243	63,232	70,554	99,840	36,608			462,392

[z]Monthly fruit yields estimated from experimental crops at the University of Florida (Jovicich, 2001; Shaw and Cantliffe, 2002). 1.0 kg·m^{-2} = 0.21 lb/ft^2.
[y]T = transplant; seeding date = 1 July; transplant date = 4 Aug.; end of crop = 30 May; harvesting period = November–May.
[x]Average wholesale prices (1993–2002) for transactions of imported greenhouse-grown bell peppers at the Miami terminal market.
[w]Mean for the harvesting period November–May. $1.00/kg = $0.454/lb. The annual mean was $4.80/kg ($2.18/lb).
[v]Gross revenue = $1.00/m^2 ($0.093/ft^2).
[u]The gross revenue was $58.98/m^2 ($5.48/ft^2) for the total greenhouse area because the growing area was 85% of the total area.

Table 7. Summary of the investment costs and depreciation of a 0.78-ha (1.927 acre) greenhouse operation for bell pepper production.

Invested item	Original cost ($/0.78 ha)[z]	Original cost ($/m²)[y]	Projected life (years)	Depreciation/year ($/0.78 ha)	Depreciation/year ($/m²)
Site preparation					
Labor leveling, compacting	20,000	2.55			
Limerock and millings	6,000	0.77			
Water piping to greenhouse complex	5,000	0.64			
Site electrical/communications to complex	20,000	2.55			
Total site work	**51,000**	**6.51**			
Greenhouse permit	**1,500**	**0.19**			
Greenhouse structure and cover materials					
Columns, arch, gutters, polyethylene locking profiles	86,600	11.05	20	4,330	0.55
Access gates, four pavilions	3,400	0.43	10	340	0.04
Side-wall and roof-vent motors	14,900	1.90	10	1,490	0.19
Insect proof netting, 50-mesh (all openings)	3,860	0.49	10	386	0.05
Polyethylene cover	8,740	1.11	3	2,913	0.37
Thermal and shading screen	41,800	5.33	10	4,180	0.53
Freight overseas–Gainesville	10,000	1.28	10	1,000	0.13
White ground cover	5,280	0.67	7	754	0.10
Total greenhouse structure and cover materials	**174,580**	**22.27**		**15,394**	**1.96**
Greenhouse erection and concrete (by contractor)	**160,000**	**20.41**	10	**16,000**	**2.04**
Construction supervision	**6,000**	**0.77**	10	**600**	**0.08**
Head house structures (15 × 10 m)[x]	**20,000**	**2.55**	20	**1,000**	**0.13**
Fruit size grading machine	**5,000**	**0.64**	10	**500**	**0.06**
Refrigeration room	**20,000**	**2.55**	20	**1,000**	**0.13**
Backup generator	**4,000**	**0.51**	10	**400**	**0.05**
Heating and ventilation systems					
Floor mounted heating units (diesel)					
20 heating units 80,639 kcal each	51,620	6.58	10	5,162	0.66
Polyethylene convection tube (19 × 300 m per roll)	1,330	0.17	3	443	0.06
Diesel tank (11,340 L) with shading roof[v]	3,600	0.46	8	450	0.06
Site diesel plumbing	3,000	0.38	10	300	0.04
Air circulation fans (60 units)	12,000	1.53	8	1,500	0.19
Total heating and ventilation systems	**71,550**	**9.13**		**7,855**	**1.01**
Irrigation and climate control systems					
Water well and pumps	10,000	1.28	15	667	0.09
Water tanks (2 × 56,700 L each)	26,000	3.32	15	1,733	0.22
Nutrient injector and climate control system	26,495	3.38	10	2,650	0.34
Nutrient solution tanks (6 × 2000 L)	5,100	0.65	10	510	0.07
Weather station and temperature and humidity sensors	8,000	1.02	10	800	0.10
Computer and software	5,000	0.64	5	1,000	0.13
Training for using control systems	1,500	0.19			
Water filters	700	0.09	10	70	0.01
Valves and pressure regulators	2,887	0.37	5	577	0.07
Irrigation emitters, stakes, and tubing	22,575	2.88	5	4,515	0.58
Polyethylene pipe (5700 m)	1,583	0.20	5	317	0.04
Pipe connectors and adaptors	550	0.07	5	110	0.01
Other irrigation parts and labor	5,000	0.64	5	1,000	0.13
11.4-L nursery pots	14,700	1.88	5	2,940	0.38
Total irrigation and climate control systems	**130,190**	**16.61**		**16,889**	**2.17**
Electrical	**80,000**	**10.20**	10	**8,000**	**1.02**
Drainage system (troughs, pipes, pump)	**3,120**	**0.40**	5	**624**	**0.08**
Bulk storage tanks (three tanks of 7600 L each)	**12,300**	**1.57**	10	**1,230**	**0.16**
Trellis accessories					
Cables for plant support (5400 m) and "U" clamps	5,600	0.71	10	560	0.07
Poles for plant support (13 per row)	6,500	0.83	10	650	0.08
Stem ring clips	1,050	0.13	2	525	0.07
Total trellis accessories	**13,150**	**1.68**		**1,735**	**0.22**

Table 7 continued on next page.

Table 7. Continued from previous page.

Invested item	Original cost ($/0.78 ha)[z]	Original cost ($/m²)[y]	Projected life (years)	Depreciation/year ($/0.78 ha)	Depreciation/year ($/m²)
Automotive (medium-duty delivery truck)	**40,000**	**5.10**	10	**4,000**	**0.51**
Fork lift	**12,000**	**1.53**	10	**1,200**	**0.15**
Other durables					
Scales	1,500	0.19	5	300	0.04
Sprayer and fogger	2,000	0.26	5	400	0.05
pH meter	150	0.02	5	30	0.00
Electrical conductivity meter	250	0.03	5	50	0.01
Ion meters for nitrate and potassium	700	0.09	4	176	0.02
Harvest trolleys	1,500	0.19	6	250	0.03
Harvest bins	6,000	0.77	6	1,000	0.13
Tools	4,000	0.51	4	1,000	0.13
Total other durables	**16,100**	**2.05**		**3,205**	**0.41**
Total investment	**820,490**	**104.67**		**79,632**	**10.18**

[z]$1.00/0.78 ha = $1.28/ha = $0.519/acre.
[y]$1.00/m² = $0.093/ft².
[x]1.0 m = 3.28 ft.
1.0 kcal = 3.97 Btu
[v]1.0 L = 0.26 gal.

Table 8. Estimated fixed costs to produce bell pepper in a 0.78-ha (1.927 acre) greenhouse in north-central Florida.

Item	Total ($/0.78 ha)[z]	Total ($/m²)[y]
Depreciation	**79,632**	**10.18**
Other fixed costs		
Repairs and maintenance	6,000	
Taxes and licenses	1,600	
Greenhouse insurance	4,000	
Vehicle insurance	1,500	
Telephone	4,500	
Other expenses	2,500	
Total other fixed costs	**20,100**	**2.56**
Total fixed costs	**99,732**	**12.74**

[z]$1.00/0.78 ha = $1.28/ha = $0.519/acre.
[y]$1.00/m² = $0.093/ft².

The price received by the grower was assumed to be the average wholesale market price less the sales transaction cost. Gross revenue was the product of the price received by the grower and the total production. Profit was calculated by subtracting total expenses from gross revenue. The opportunity costs (interest on operating capital and on investment capital), land charge (rent), and cost of managing the enterprise (manager's salary) were not included as specific expenses in this budget, and, thus, were part of the residual net return or loss. Because the opportunity cost for management, operating capital, and investment capital were not incorporated in the enterprise budget, the estimated profit should be interpreted as "estimated returns to capital and management." The formula used to calculate profit (in $/unit area or $/total area) was: returns to management and capital ($/unit or total area) = gross revenue ($/unit or total area) – total costs ($/unit or total area).

The profitability of the 0.78-ha enterprise (excluding the land) was estimated by the relation between the value of return and the investment. The internal rate of the return to invested capital and management from the total investment (IRR) was calculated with the following formula: IRR (%) = returns to capital and management ($/total area) × 100 ÷ total investment ($/total area). The estimated IRR was compared to the opportunity cost of capital using the average interest rate for bank loans to business for the year period 1993–2003.

From the budget analysis, gross revenues, production costs, and returns were plotted and linear equations calculated for a range of marketable fruit yields (5–17 kg·m^{-2}), assuming the average fruit price for the November–May period ($5.29/kg).

Sensitivity analysis. Sensitivity analysis was used to analyze how changes in budget assumptions affect income and cost projections. Returns to management were calculated for a range of marketable fruit yields (5–17 kg·m^{-2}) and market prices [$15.00–32.50/5-kg carton ($1.36–2.95/lb)]. In the sensitivity analysis, market prices were assumed to be average values for the November–May harvest period.

Break-even analysis. The data in the enterprise budget were used to perform a break-even analysis. This analysis was used to calculate various combinations of possible yield and prices required to cover anticipated total production costs. Break-even prices were calculated using the formula: break-even price ($ per unit weight) = anticipated total costs ($ per unit area) ÷ anticipated yield (weight per unit area).

Results

Prices for mature ripened bell pepper fruits. Historical wholesale market prices at the Miami terminal market indicate that mature ripened greenhouse-grown bell pepper fruits attracted average prices three to five times higher than mature ripened or green fruits grown in the field, respectively (Fig. 5). Red and yellow fruits produced in the field had average annual fruit prices (hereafter, mean price ± SD) of $1.51 ± 0.41/kg ($0.68 ± 0.19/lb) and $1.69 ± 0.53/kg ($0.77 ± 0.24/lb), respectively, with peak prices close to $2.00/kg ($0.91/lb) in July, August, and November (Fig. 5). The average price for mature green fruits was only $0.91 ± 0.24/kg ($0.41 ± 0.11/lb) and with minimal price fluctuations throughout the year. Imported red, yellow, and orange fruits produced in greenhouses averaged $4.68 ± 0.71/kg, $4.52 ± 0.66/kg, and $5.21 ± 0.76/kg ($2.12 ± 0.32/lb, $2.05 ± 0.30/lb, and $2.36

Table 9. Estimated variable costs to produce bell pepper in a 0.78-ha (1.927 acre) greenhouse in north-central Florida.

Item	Unit	Quantity (no. units)	Price ($/unit)	Amount ($/0.78 ha)[z]	Total ($/0.78 ha)	Total ($/m²)[y]
		Production costs				
Preharvest						
Fertilizer					13,978	1.78
480 g/plant used in 298 d	kg[x]	9,984	1.40	13,978		
Biologicals					3,610	0.46
A. colemani (1/m²), two releases	×500	40	35.00	1,400		
N. californicus (10/m²), one release	×1000	67	30.00	2,010		
B. thuringiensis, two drain applications	9.45-L[w]	2	100.00	200		
Pesticides					1,078	0.14
Fungicides[v]	Spray	15	60.00	900		
Miticide[u]	Spray	1	120.00	178		
Pollinators					880	0.11
Bumblebees	50 bees/hive	4	220.00	880		
Other materials inputs					13,937	1.78
Twine spool × 3000 m[t]		8	13.00	104		
Double hooks	unit	16,000	0.01	160		
Bleach	L	154	0.26	40		
Seedling trays	unit	110	3.00	330		
Media seedlings	m³	1.2	70.00	84		
Seed	unit	21,840	0.35	7,644		
Media for pots (perlite)	m³	260	40.00	5,200		
Sticky cards (insect pest monitoring)	box × 100	30	25.00	375		
Energy					38,284	4.88
Diesel	L	135,708	0.26	35,284		
Electricity[s]	kWh	30,000	0.10	3,000		
Labor		Times	Total h		18,421	2.35
Seeding and seedling growing	h	1	120	886		
Preparation greenhouse	h	1	363	2,679		
Transplanting	h	1	58	428		
Plant support with twines and hooks	h	6	333	2,458		
Removal of cull fruits, old leaves and shoots	h	2	150	1,107		
Fertilizer preparation	h	13	39	288		
Solution monitoring and filter cleaning	h	30	60	864		
Scouting (pests, diseases and beneficials)	h	35	140	2,520		
Removal of plants and cleaning	h	1	480	3,542		
Polyethylene cover change (every 3 years)	h	0.33	81	199		
Pesticide application	h	15	195	2,808		
Empting and washing of pots (every 2 years)	h	0.5	174	642		
Total labor	h		2,052			
Total preharvest costs					**90,188**	**11.50**
Harvest						
Picking labor (75 h/harvest × 30 harvests)	h	2,250	7.38	16,605		
Total harvest costs					**16,605**	**2.12**
Packing and marketing						
Pack labor (1,442 h)	kg	86,528	0.12	10,383		
Cartons, dividers and labels	kg	86,528	0.16	13,845		
Marketing and miscellaneous packing	kg	86,528	0.22	19,036		
Vehicle operation	km[r]	16,000	0.19	3,000		
Total packing and marketing costs					**46,264**	**5.90**
Total production costs					**153,057**	**19.52**

[z]$1.00/0.78 ha = $1.28/ha = $0.519/acre.
[y]$1.00/m² = $0.093/ft².
[x]1.0 kg = 2.20 lb.
[w]1.0 L = 0.26 gal.
[v]azoxystrobin, myclobutanil, and *Ampelomyces quisqualis.*
[u]abamectin.
[t]1.0 m = 3.28 ft.
[s]Electric energy unit is kilowatt–hour (kWh).
[r]1.0 km = 0.62 miles.

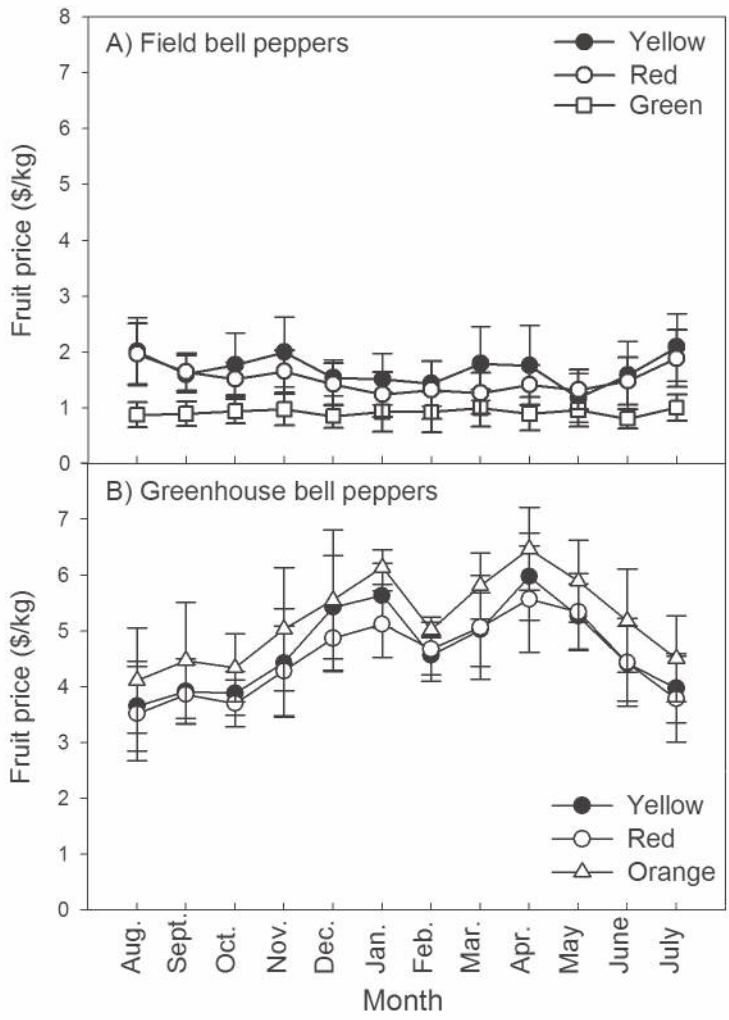

Fig. 5. Means and standard deviations for bell pepper fruit wholesale prices from years 1993 to 2002 obtained from Thursdays' transactions at the Miami terminal market: A) prices for yellow (●), red (○), and green (❑) fruits produced in the field (shipped from Florida, California, Georgia, and North Carolina), and B) prices for yellow (●), red (○), and orange (Δ) fruits imported and produced in greenhouses (shipped from The Netherlands, Israel, and Spain). $1.00/kg = $0.454/lb.

± 0.34/lb), respectively (Fig. 5). For greenhouse-grown fruits, average prices for all fruit colors combined attracted high values during the period November–May [$5.29 ± 0.78/kg ($2.40 ± 0.35/lb)] while peak prices were in January [$5.63 ± 0.50/kg ($2.55 ± 0.23/lb)] and April [$6.00 ± 0.82/kg ([$2.72 ± 0.37/lb)]. For the whole year, the average price for colored fruits produced in greenhouses was $4.80 ± 0.71/kg ($2.18 ± 0.32/lb). The annual average price per unit weight for mature ripened bell pepper fruits produced in greenhouses was an additional $3.20/kg ($1.45/lb) compared to mature ripened fruits produced in the field, and an additional $3.89/kg ($1.76/lb) compared to mature green fruits.

Investment and costs. The total investment for a greenhouse enterprise with a protected area of 0.78 ha totaled $820,490 or $104.67/m^2 ($9.72/ft^2) (Table 7). The cost of the greenhouse structure and cover materials combined was $22.27/m^2 ($2.07/ft^2) and, with construction labor, supervision, and concrete needed for erection, the cost increased to $43.45/m^2 ($4.04/ft^2) (Table 7). The investment on heating and ventilation systems was estimated at $9.13/m^2 ($0.85/ft^2), and on systems and controls for irrigation, fertilization, drainage, and ventilation was $16.61/m^2 ($1.54/ft^2). The annual depreciation cost for the total investment was $10.18/m^2 ($0.95/ft^2). Additional expenses within fixed costs represented $2.56/m^2 ($0.24/ft^2) (Table 8). Total fixed costs added to $12.74/m^2 ($1.18/ft^2).

Preharvest costs were estimated at $11.50/m^2 ($1.07/ft^2), harvest costs at $2.12/m^2 ($0.20/ft^2), and packing and marketing at $5.90/m^2 ($0.55/ft^2) (Table 9). These variable costs combined added to $19.52/m^2 ($1.81/ft^2). The total labor needed to produce, harvest and pack the bell pepper fruits was 5,744 hours [0.73 h/m^2 (0.068 h/ft^2)] and represented $45,409 for the 0.78 ha [$5.79/m^2 ($0.54/ft^2)] (Table 9). From this total labor, 35.7% of the time was used to grow the crop, 39.2% for harvesting, and the remaining 25.1% for packing the fruits (Table 9). The total cost of diesel fuel used for heating was estimated at $35,284 [$4.50/m^2 ($0.42/ft^2)].

Budget analysis. The summary for the budget analysis (Table 10) included fixed (Table 8) and variable costs (Table 9). Adding the sales transaction expenses [15% of the gross revenue, equivalent to $8.85/m^2 ($0.82/ft^2)] to the variable costs of production [$19.52/m^2 ($1.81/ft^2)], the total variable cost was $28.37/m^2 ($2.64/ft^2) (Table 10). Total costs (fixed and variable) amounted to $41.09/m^2 ($3.82/ft^2) ($322,148 for the 0.78 ha). From this total cost, depreciation cost represented 24.7%, transaction cost 21.5%, cost of total labor 14.1%, and cost of fuel 11.0% of the total cost (Table 10).

With a marketable fruit yield of 13 kg·m^{-2} harvested during the period November–May, the estimated gross revenue was $58.98/m^2 ($5.48/ft^2) ($462,392 for the 0.78 ha) (Table 6). The return to capital and to management was $140,244 for the total greenhouse area, or $17.89/m^2 ($1.66/ft^2) (Table 10). The IRR to invested capital and management (excluding the land) was estimated at 17.1%.

Gross revenues, production costs, and returns were calculated for a range of marketable fruit yields (5–17 kg·m^{-2}), assuming the average price for the period November–May ($5.29/kg) (Fig. 6). Total costs increased with increased fruit yields because of the need for additional labor for harvesting and packing, and of more packing supplies. The estimated linear responses indicate that returns to capital and management were zero when a marketable fruit yield of 7.8 kg·m^{-2} was obtained in the growing area. Under the assumptions

Table 10. Enterprise budget for greenhouse-grown bell pepper [0.78 ha (1.927 acres)] in north-central Florida.

Item	Unit	Quantity (no. units)	Price ($/unit)	Amount ($/0.78 ha)[x]	Total ($/0.78 ha)	Total ($/m²)[w]
Gross revenue	kg[z]	86,528	4.58–6.00[y]		462,392	58.98
Variable costs						
Preharvest						
Fertilizer				13,978		
Biologicals				3,610		
Pesticides				1,078		
Pollinators				880		
Other material inputs				13,937		
Diesel	L[v]	135,708	0.26	35,284		
Electricity[u]	kWh	30,000	0.10	3,000		
Labor	h	2052		18,421		
Total preharvest costs					90,188	11.50
Harvest						
Labor	h	2,250	7.38	16,605		
Total harvest costs					16,605	2.12
Packing and marketing						
Pack labor (1442 h)	kg	86,528	0.12	10,383		
Cartons, dividers, and labels	kg	86,528	0.16	13,845		
Marketing and miscellaneous packing	kg	86,528	0.22	19,036		
Vehicle	km[t]	16,000	0.19	3,000		
Total packing and marketing costs					46,264	5.90
Total above variable costs					153,057	19.52
Sale transaction expenses (15%)		0.15	462,392	69,359	69,359	8.85
Total variable costs					222,416	28.37
Fixed costs						
Depreciation				79,632		
Other fixed costs				20,100		
Total fixed costs					99,732	12.74
Total cost					322,148	41.09
Return to capital and management[s]					140,244	17.89

[z]1.0 kg = 2.20 lb.
[y]Range of average wholesale prices for greenhouse-grown bell peppers during the harvest period. Gross revenue was the sum of estimated monthly revenues. Revenues in each month were calculated as the product of the average market price by the estimated monthly yield [total estimated fruit yield = 13 kg·m^{-2} (2.7 lb/ft^2) of growing area].
[x]$1.00/0.78 ha = $1.28/ha = $0.519/acre.
[w]$1.00/m^2 = $0.093/ft^2.
[v]1.0 L = 0.26 gal
[u]Electric energy unit is kilowatt–hour (kWh).
[t]1.0 km = 0.62 miles.
[s]Land, opportunity costs (interest on investment capital and interest on operating capital), and the grower's salary were not included in the budget.

of this budget analysis, break-even yield was similar to the average fruit yield of 7.9 kg·m^{-2} (1.62 lb/ft^2) that was estimated from data collected by the 1998 Census of Specialty Crops (U.S. Dept. of Agriculture, 1998) (Table 4). Currently, fruit yields of 10 to 15 kg·m^{-2} (2.0 to 3.1 lb/ft^2) are realistic in fall to spring crops such as the one used in this analysis. A marketable fruit yield of 17 kg·m^{-2} (3.5 lb/ft^2), which is considered a high yield in structures with minimal climate control in subtropical regions, led to an estimated return of $30.84/m^2 ($2.87/ft^2) (Fig. 6).

SENSITIVITY ANALYSIS AND BREAK-EVEN ANALYSIS. A sensitivity analysis was used to examine how returns to capital and management changed under favorable and unfavorable situations of fruit production and market price (Table 11). Changes in returns from negative to positive values were calculated under various combinations of marketable yields (5–17 kg·m^{-2}) and fruit prices [$15.00–32.50 per 5-kg carton, as average values for the November–May harvest season]. Costs of production (with sales transaction expenses deducted) ranged from $28.61/m^2 to $34.96/m^2 ($2.66/ft^2 to $3.25/ft^2) based on a range of possible marketable fruit yields of 5 to 17 kg·m^{-2}, respectively (Table 11). Returns for the 0.78 ha are included in Table 11.

Break-even prices (in $/kg and $/carton) required to cover anticipated total production costs were calculated for various possible fruit yields (Table 12). For fruit yields ranging from 5 to 17 kg·m^{-2}, the break-even prices ranged from $39.73 to $13.90/5-kg carton ($3.60 to $1.26/lb).

Discussion

Much of the U.S. demand for high quality colored pepper is currently supplied by imports. The value and yield of colored fruits produced per unit area in greenhouses can be three or five times higher compared to colored and green pepper fruits grown in the field, respectively. Imported greenhouse-grown peppers (as with tomatoes and cucumbers) compete with field-grown crops in the U.S. (Cantliffe and VanSickle, 2001). Moreover, in Florida, high quality colored pepper fruits produced in greenhouses

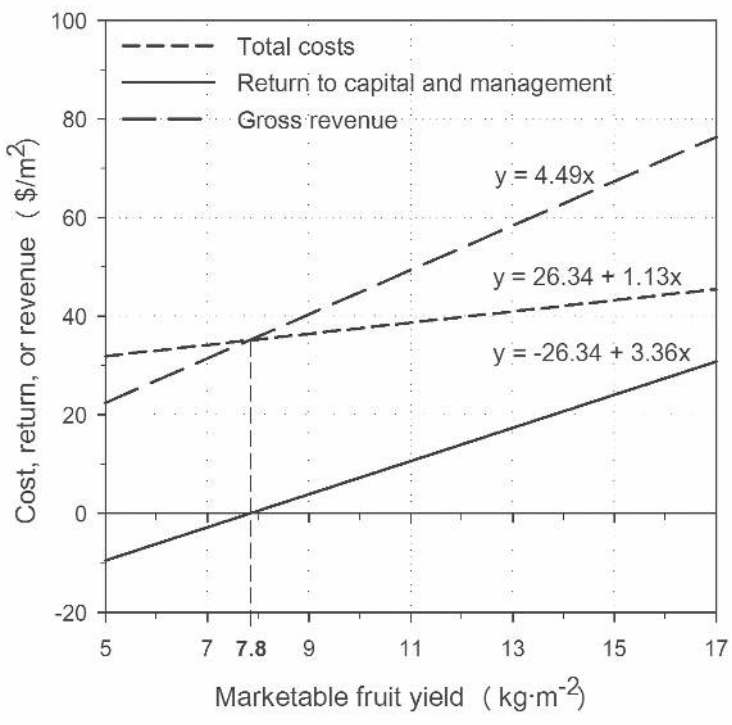

Fig. 6. Estimated responses of total costs, returns to capital and management (excluding cost of land), and gross revenues to increased marketable fruit yields of greenhouse-grown bell peppers in north-central Florida. Costs, revenues, and returns based on unit area of a 0.78-ha (1.927-acre) greenhouse. Fruit yields expressed per unit of growing area. Average fruit wholesale price for the production season was estimated at $5.29/kg ($2.40/lb). Returns to capital and to management were 0 (zero) at fruit yield of 7.8 kg·m^{-2} (1.60 lb/ft^2); $1.00/m^2 = $0.093/ft^2; 1.0 kg·m^{-2} = 0.21 lb/ft^2.

Table 12. Estimated break-even prices for a range of marketable bell pepper fruit yields of 5–17 kg·m^{-2} (1.0–3.5 lb/ft^2).

Yield in growing area[z]		Break-even price[y]	
(kg·m^{-2})	(carton/m^2)	($/kg)	($/5-kg carton)
5.0	1.0	7.95	39.73
7.0	1.4	5.84	29.22
7.8	1.6	5.29[x]	26.45
9.0	1.8	4.68	23.40
11.0	2.2	3.94	19.71
13.0	2.6	3.43	17.15
15.0	3.0	3.07	15.35
17.0	3.4	2.78	13.90

[z]Fruit yields are expressed on a growing floor area basis; 1.0 kg·m^{-2} = 0.21 lb/ft^2; 1.0 carton = 5 kg (11.0 lb); 1.0 carton/m^2 = 0.09 carton/ft^2.
[y]$1.00/kg = $0.454/lb; $1.00/5-kg carton = $0.091/lb.
[x]Average wholesale price for transactions of imported greenhouse-grown peppers at the Miami terminal market during November–May and over the year period 1993–2002.

Table 11. Sensitivity analysis for bell pepper returns to capital and management per unit area and in the 0.78-ha (1.927-acre) greenhouse.

Yield[z]	Cost[y]	Market price[x] ($/5-kg carton)								
(kg·m^{-2})	($/m^2)	15.00	17.50	20.00	22.50	25.00	26.45[w]	27.50	30.00	32.50
		Return $/m^2 ($/0.78 ha)								
5	28.61	**–17.79**	**–15.98**	**–14.18**	**–12.37**	**–10.57**	**–9.52**	**–8.77**	**–6.96**	**–5.16**
		(–139,439)	**(–125,296)**	**(–111,153)**	**(–97,010)**	**(–82,868)**	**(–74,665)**	**(–68,725)**	**(–54,582)**	**(–40,440)**
7	29.52	**–14.36**	**–11.84**	**–9.31**	**–6.79**	**–4.26**	**–2.80**	**–1.74**	0.79	3.31
		(–112,612)	**(–92,812)**	**(–73,012)**	**(–53,212)**	**(–33,413)**	**(–21,929)**	**(–13,613)**	(6,187)	(25,987)
9	30.42	**–10.94**	**–7.69**	**–4.45**	**–1.20**	2.05	3.93	5.29	8.54	11.79
		(–85,785)	**(–60,328)**	**(–34,871)**	**(–9,414)**	(16,042)	(30,807)	(41,499)	(66,956)	(92,413)
11	31.33	**–7.52**	**–3.55**	0.42	4.39	8.35	10.66	12.32	16.29	20.26
		(–58,958)	**(–27,844)**	(3,270)	(34,384)	(65,498)	(83,544)	(96,611)	(127,725)	(158,839)
13	32.24	**–4.10**	0.59	5.28	9.97	14.66	17.38	19.35	24.04	28.73
		(–32,131)	(4,640)	(41,411)	(78,182)	(114,953)	(136,280)	(151,724)	(188,495)	(225,265)
15	33.15	**–0.68**	4.74	10.15	15.56	20.97	24.11	26.38	32.79	37.21
		(–5,304)	(37,124)	(79,552)	(121,980)	(164,408)	(189,016)	(206,836)	(249,264)	(291,692)
17	34.96	2.75	8.88	15.01	21.15	27.28	30.84	33.41	39.55	45.68
		(21,522)	(69,608)	(117,693)	(165,778)	(213,863)	(241,752)	(261,948)	(310,033)	(358,118)

[z]Fruit yields are expressed on a growing floor area basis but returns are based on unit area of 0.78 ha. 1.0 kg·m^{-2} = 0.21 lb/ft^2. Fruit yields on a growing floor area basis multiplied by 0.85 give the yield on a unit area of the total 0.78 ha.
[y]Total production costs without the sales transaction cost included. The transaction cost (15%) was deducted from the gross revenues for each yield–price combination; $1.00/m^2 = $0.093/ft^2; $1.00/0.78 ha = $1.28/ha = $0.519/acre.
[x]Average market price for the harvest period November–May; $1.00/5-kg carton = $0.091/lb.
[w]Average wholesale price for transactions of imported greenhouse-grown peppers at the Miami terminal market during November–May and over the year period 1993–2002 [$5.29/kg ($2.40/lb)].

compete with imports from Mexico, The Netherlands, Canada, Israel, and most recently, Spain. However, the high and steady market prices attracted by colored bell pepper fruits in the past years, increases in consumer demand, and suitable environment for growing colored peppers under protected agriculture in Florida have led to a small but expanding production area and have driven more growers to consider the economic viability of this crop.

Green and colored peppers produced in the field and greenhouse, respectively, are different types of commodities, which have different production costs and attract different market prices. In our analysis, for the fruit yield of 13 $kg \cdot m^{-2}$, the estimated total cost of producing colored peppers in the greenhouse was \$41.09/m^2 and the return to management and capital was \$17.89/m^2. Using estimates by Smith and Taylor (2004) as a reference, a field-grown pepper crop in Florida with a fruit yield of 31.4 $t \cdot ha^{-1}$ [14 tons/acre (1000 bu/acre at 28 lb/bu)] incurred a production cost of \$2.53/m^2 (\$0.24/ft^2) and a return to management and capital of \$0.61/m^2 (\$0.06/ft^2) based on a market price of \$1.00/kg (\$0.45/lb).

Under the greenhouse crop management practices and market prices used in this study, fruit yields should be greater than 7.8 $kg \cdot m^{-2}$ in order to generate positive returns to management. This break-even yield is a realistic goal in Florida because greater yields are currently obtained in greenhouse enterprises similar to the one considered in this analysis. In experimental and commercial crops, yields of 10 to 15 $kg \cdot m^{-2}$ were possible when production practices and length of the growing season were similar to the ones described here. The estimation of probabilities for alternative yield outcomes will be completed in an upcoming research project. These estimates will make additional interpretation of the sensitivity analyses possible.

An investment would be profitable when the internal rate of return for the investment is greater than the opportunity cost of capital (Kay and Edwards, 1994). The IRR of the 0.78-ha greenhouse enterprise was greater than the average interest rate for bank loans to business for the past 10 years (7.3% as an average in the period 1993–2003) (Federal Reserve, 2004). The estimated IRR was within the range of rates of return (8.5% to 19.4%) calculated by Hodges et al. (2001) for large greenhouse nurseries that produced ornamentals in Florida in 1998. A cash flow analysis for a series of years, which would include interest on the capital investment, could supplement the budget analysis.

Greenhouse enterprises, even when located in a small region, are variable in size, composition, and management. As such, growers seeking to produce peppers in greenhouses should use this information only as a guide and calculate the budgets for their own enterprises. The initial capital investment will differ among greenhouse enterprises; however, per unit area, it is always considerably high compared to investments in field vegetable production. For this budget analysis, we considered the state's smallest greenhouse area with bell pepper. It is expected that larger greenhouse enterprises will benefit from economies of scale and will incur relatively lower costs of production per unit area.

NaLampang et al. (2003), in their calculations of demand elasticities for green bell peppers for four regional markets in the U.S., found an inelastic demand for green peppers, with elasticities ranging from –0.10 to –0.24. No comparable studies have been carried out for colored bell peppers. However, it is expected that the demand elasticity for colored bell peppers would be more elastic, indicating more room for relative production growth as efficiencies are identified in the production and marketing of colored bell peppers.

Vegetable growers in Florida currently face production challenges in terms of marketing (demand for high quality products with year-round supply and foreign competition), land availability (increased urbanization and development in "warm weather" agricultural areas), labor (reduced availability with the appearance of higher-paying jobs, such as in the construction business), water restrictions (stricter regulations to protect water quality and to minimize amounts used), and the upcoming banning of methyl bromide (Montreal Protocol on ozone protection resolutions). For some growers, the production of high value crops such as colored bell peppers in greenhouses using soilless growing systems may represent an alternative production system that would overcome some of these critical challenges and would assist their continuation in the agricultural business.

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