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ECONOMIC FEASIBILITY OF PRODUCING STRAWBERRIES IN A PASSIVELY VENTILATED GREENHOUSE IN NORTH-CENTRAL FLORIDA

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Abstract. **The economic feasibility of a 1-ha greenhouse strawberry enterprise was analyzed. Results from greenhouse studies conducted at the UF Protected Ag Project indicated that average yields of 11 kg m^{-2} (110 tons per ha) can be obtained under north-central Florida conditions. These yields are 3-4 times greater than those obtained from field-grown strawberries in west-central Florida. Based on average yields of 11 kg m^{-2} from November to March, and average market prices ranging from $2.10/kg in March to $3.81/kg in December, a gross income of $32.31/m^2 or $323,100/ha can be obtained. The fixed cost (or initial investment) of a 1-ha passively ventilated greenhouse designed for producing strawberries was estimated at $76.27/m^2 or $762,760/ha, and the annual depreciation cost on the initial investment was estimated at $6.70/m^2 or $66,976/ha. The variable cost for producing strawberries in a 1-ha passively ventilated greenhouse at a plant density of 22 plants per m^2 and average yields of 500 g per plant (11 kg m^{-2}) was estimated at $20.91/m^2 or $209,075/ha. The total cost (annual depreciation on fixed cost + variable cost) for producing 1 ha of greenhouse strawberries was $28.54/m^2 or $285,351/ha. With average yields of 11 kg m^{-2} and monthly market prices ranging from $2.10/kg in March to $3.81/kg in December, a net annual income of $3.77/m^2 or $37,749/ha can be obtained above the total cost. 'Pesticide-free' strawberries and specialty 'stem-berries' could potentially be sold at a premium price, and may lead to substantially higher net returns. Thus, greenhouse strawberry production can be considered an economically viable alternative to conventional field strawberry production in Florida.**

Florida's strawberry (*Fragaria × ananassa* Duch.) industry, valued at $135 million (Fla. Dept. Agr. Consumer Serv., 2002), is known for its winter fruit production. With an annual production of 78,600 tons, it is the second largest strawberry producer in the U.S. after California (Fla. Dept. Agr. Consumer Serv., 2002). However, conventional strawberry production in Florida is facing a number of challenges that could threaten its economic future. After the phase-out of methyl bromide in January 2005, the use of 1, 3-dichloropropene and devrinol mixture, considered by far the best chemical alternative to methyl bromide soil fumigation in Florida, may still lead to a yield reduction of 15-20 percent (VanSickle, 2000). Additionally, frequent occurrence of freeze events as evidenced in recent years may further reduce early yields and cause economic

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losses. Rapid urbanization in west-central Florida, also the hub of Florida's strawberry industry, has caused land prices to appreciate enormously, making it difficult for traditional strawberry farmers to resist the lure of lucrative land deals. Demand for water from nearby urban settlements is constantly increasing, which has led to restrictions being imposed on water usage by strawberry farms. Labor cost for harvesting strawberries, which accounts for almost 50% of the total cost of field strawberry production, may increase considerably in the future. Also, it may become more difficult to recruit labor for harvesting strawberries as younger generations of the migrant Hispanic population receive better education and may undertake jobs that are physically less demanding and pay higher wages (Chandler et al., 1993). Other concerns for the Florida strawberry industry include the massive solid waste disposal problem created by extensive use of non-reusable polyethylene mulch (Chandler et al., 1993), and EPA regulations aimed at preventing pesticide spray drifts from strawberry farms to nearby urban settlements. Thus, strawberry farming in the midst of Florida's most populous area is becoming increasingly difficult, and there is a need to consider alternatives such as 'protected culture' in order to ensure the economic future of the strawberry industry in Florida.

Greenhouse vegetable production in countries such as Spain, Israel, Canada, Mexico, and Holland is highly profitable because the growers are able to produce an excellent quality product at a competitive price. Recently, imports of fresh vegetables from these countries have started to increase as U.S. consumers are demanding a high quality product. In order to maintain their place in the fresh produce market in the eastern U.S., vegetable growers in Florida could benefit by adopting greenhouse production techniques. Although majority of Florida vegetables are produced in open fields without protection from adverse weather, a few growers have been growing vegetables under protected culture for the past three decades.

Throughout the world, protected culture is widely used to advance or extend the strawberry season (Hancock and Simpson, 1995), and could provide a sound alternative to conventional strawberry production in Florida. Some of the countries where strawberries are grown under protected culture on a large scale are Japan (8,000 ha) (Takeda, 2000), South Korea (7,500 ha) (Kang and Oh, 1996), Italy (3,025 ha), Spain (2,000 ha), Morocco (935 ha), United Kingdom (600 ha), Belgium (520 ha), France (420 ha), Portugal (300 ha), Holland (160 ha) (Lieten, 2001), and Israel (45 ha) (Itzhak Secker, personal communication). Use of soilless growing substrates combined with protected culture would eliminate the need for methyl bromide in strawberry production (Takeda, 2000). Chemical usage in soilless culture is very low, since soil disinfection with chemicals is not necessary due to reduced risks of soil borne diseases, and the amount of herbicides used is virtually reduced to zero (Lieten, 2003b). Effective use of biological pest management practices can further reduce the use of pesticides, improve fruit quality, and enable the grower to market the strawberries as 'pesticide free'. Also, working conditions in protected strawberry culture are generally better than outdoor culture, which makes it easier to find labor for harvesting strawberries (Lieten, 2003b). In protected culture, plug transplants are preferred over bare-root transplants. Therefore, the quantity of water needed for plant establishment is significantly reduced compared to that needed for bare-root transplants in the field. Specialized growing systems that can accommodate up to five times more plants per unit area compared to conventional field culture can not only increase yields per unit area (Paranjpe et al., 2003c), but also facilitate ease of harvest and improve harvest efficiency by 25-30 percent (M. Dinar and N. Gnayem, 2003; personal communication). Strawberries grown under protected culture are cleaner since they do not come in contact with soil or splashing water, and can be harvested with long stems for specialty marketing.

In order to ascertain whether greenhouse strawberry production can be profitable under Florida's unique climatic, geographic, and socioeconomic conditions, it was necessary to conduct a detailed feasibility study based on the actual costs, yields, and market prices that a grower in Florida will encounter. In this paper, a detailed economic feasibility study is presented based on average yields obtained in experimental studies in north-central Florida and historical market prices compiled by USDA-AMS, and by considering the actual costs of labor and material need for setting up and operating a greenhouse strawberry enterprise in Florida. Sample costs serve as a guide only, since costs and returns may vary considerably over different regions and with individual preferences for product brands and quality.

Materials and Methods

The feasibility study was based on three main independent variables: gross return, fixed cost (and depreciation), and variable cost.

Gross return. Gross return is the gross cash inflow obtained by selling the product at prevailing market prices, and is calculated as:

Gross return = Marketable yield × F.O.B shipping point prices

Fixed cost. Fixed cost (also called 'initial investment') includes the cost of all materials (e.g., greenhouse structure, growing containers, heating equipment, transport vehicles, etc.) and the labor costs that would be incurred regardless of the type of crop grown or the number of crops grown in a year. Generally, most of these costs are non-recurring. Other costs such as the cost of land, opportunity costs (interest on investment capital), and grower's salary are not considered in this enterprise budget. The annual depreciation value of each item included in the fixed cost was calculated as:

Depreciation on fixed cost = Fixed (Initial) cost ÷ Expected life (years)

Variable cost. Variable cost (also called 'production cost') includes the cost of all inputs (e.g., plants, soilless media, fertilizer, beneficial insects, fuel energy, packing material, etc.) needed for crop production, and the labor cost for harvesting and other cultural operations. Variable cost is incurred each year, and may vary according to the type of crop grown and the number of crops grown in a year.

Net return. Net return is the income obtained by the grower above the variable (production) cost, or above the total cost, and is calculated as:

Net return above production cost = Gross return – Variable cost

Net return above total cost =
Gross return – (Dep. on fixed cost + Variable cost)

Sensitivity analysis. Typically, marketable yields can vary considerably, and are influenced by a variety of factors such as environmental conditions, crop management skills, and quality of inputs used. Market prices may also vary considerably and are driven mostly by demand and supply, and to a certain extent, by a variety of other factors such as product quality, transportation costs, and distance from terminal markets. A sensitivity index is presented, wherein a wide range of potential marketable yields (including the average yields obtained in experimental studies in north-central Florida) and potential market prices (based on monthly average prices reported by USDA-AMS from 1993-2002) are considered for calculating net returns from a 1-ha greenhouse strawberry enterprise.

Results and Discussion

Yield, market prices, and gross revenue

In greenhouse studies conducted at the UF Protected Ag Project, average marketable strawberry yields of 11 kg m^{-2} or 500 g per plant were obtained from November to March. These yields compare favorably to commercial yields obtained in Israel, Spain, Portugal, and other Mediterranean countries (I. Secker and F. Arroyo, personal communication). Also, strawberry yields obtained in greenhouse studies were 3-4 times greater than typical yields obtained from conventional field strawberry production in west-central Florida.

The average annual consumption of fresh strawberries in the U.S. is 515,000 tons (1992-2001/NASS-USDA). California supplies about 80% of this demand with an annual production of 410,000 tons, Florida supplies about 8% with an annual production of 41,000 tons, and Mexico supplies 5% with an annual supply of 25,000 tons to the U.S. market (1992-2001/NASS-USDA) (Fig. 1). In addition to the 25,000 tons of strawberries imported from Mexico, another 25,000 tons of strawberries are imported from countries such as Canada, New Zealand, Argentina, and Australia (Fig. 2). Also, almost 25% (12,400 tons) of U.S. strawberry imports coincide with Florida's strawberry season (November-March).

Since the Florida strawberry industry is characterized as competitive, where no grower is large enough to influence market price, the prices obtained by Florida growers mostly depend on consumer demand and shipments from California and abroad. The average F.O.B. shipping point prices ranged from a low of $7.64 per flat in July to a high of $18.16 per flat in December (1993-2002/NASS-USDA, Table 1). The monthly F.O.B. shipping point prices averaged over 10 years (1993-2002) are presented in Figs. 3 and 4. In recent years, a small percentage of the strawberry production is being sold with stems. Half a kilogram of 'stem-berries' are packed in a 1-kg capacity plastic clamshell with bubble wrap. Stem-berries typically sell for twice the price of regular strawberries. Also, the demand from U.S. consumers for pesticide-free fruits and vegetables is increasing, and pesticide-free strawberries could potentially receive higher market prices compared with strawberries produced with pesticides. According to a survey conducted by the University of Manitoba, Canada, 28% of the people from a sample of 1,500 were willing to pay up to 10% more for pesticide-free produce (Magnasson and Cranfield, 2001). Moreover, pesticide-free strawberries are not only safer, but also contain 19% more polyphenolic antioxidants (Mitchell, 2003). However, since pesticide-free strawberries are presently not available in the U.S., establishing a market price for pesticide-free strawberries was not possible. Therefore, although the cost analysis presented is for the production of 'pesticide-free' strawberries, the market prices received by growers for conventionally grown strawberries were used for calculating the gross revenue. By assuming an

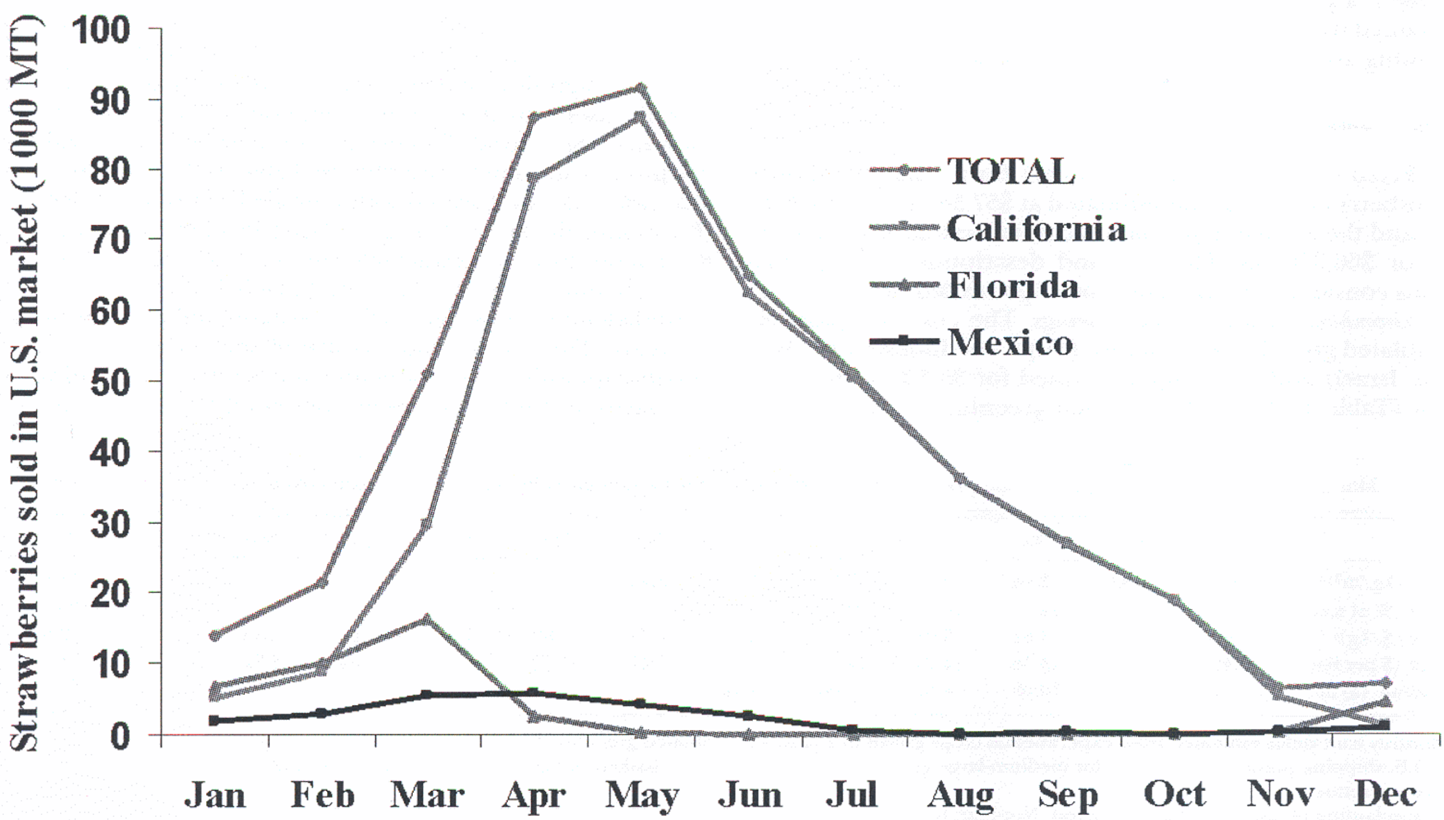

Fig. 1. Monthly U.S. and Mexico strawberry shipments (1992-2001/NASS-USDA).

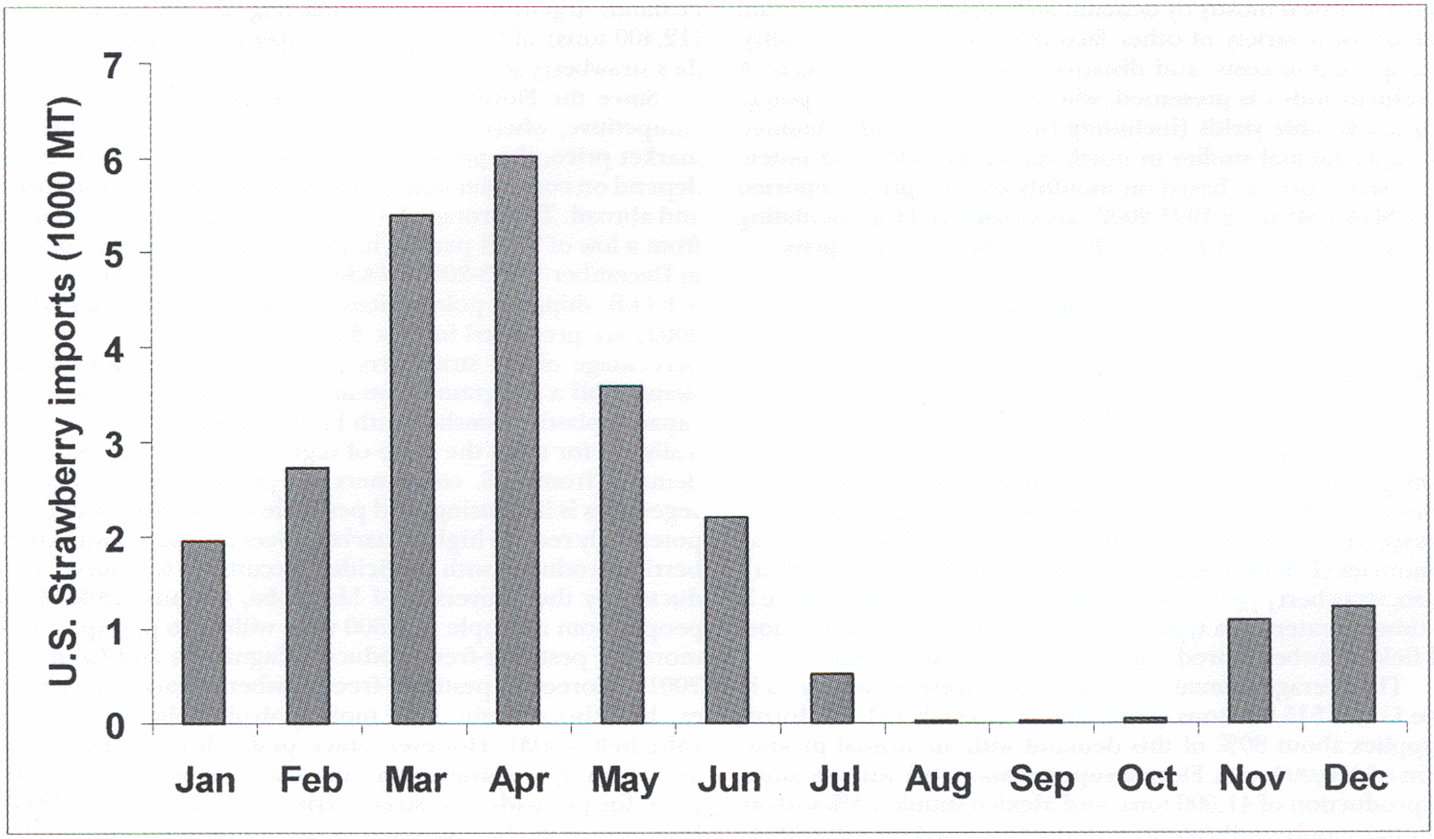

Fig. 2. U.S. strawberry imports by month (1992-2001/NASS-USDA).

average yield of 11 kg m^{-2} yield and market prices specified in Table 1, a gross revenue of $32.31/m^2 or $323,100/ha can be obtained from a greenhouse strawberry crop grown on a 1-ha growing area (1.07-ha gross greenhouse area).

Fixed costs

Fixed cost (or initial investment) for a 1-ha greenhouse strawberry enterprise was estimated at $57.38/m^2 or 573,804/ha, and the annual depreciation cost was estimated at $6.70/m^2 or $66,976/ha. The cost and description of individual items considered in the fixed cost is presented below.

Greenhouse structure and coverings. The cost of a passively ventilated greenhouse structure (Top Greenhouses Ltd., Barkan, Israel) and coverings accounted for 35.3% of the fixed cost (Table 4). Passively ventilated greenhouses are well-suited for crop production in mild winter climates. They are designed to use minimal amount of fuel energy for heating or cooling the air inside the greenhouse. Structural costs and the cost of fuel energy needed for passively ventilated greenhouses is significantly lower compared with pad-fan cooled greenhouses, which are more common in colder regions of the world. Structural dimensions of the greenhouse used for the present study are presented in Table 2. Roof and retractable side walls are covered with a single layer of polyethylene (0.150 mm thickness, Ginegar Plastic Products Ltd., Israel). Roof vents and non-retractable side walls are covered with a 50-mesh insect screen (Meteor, Petach-Tikva, Israel). The polyethylene is ultraviolet (UV) resistant, and lasts for up to 3-4 years. The UV resistant nature of the polyethylene may also disrupt whitefly reproduction and reduce the risk of virus transmission. Insect screens are designed to keep out insect

Table 1. Monthly fruit yields, F.O.B. shipping point prices, and gross revenues from a winter greenhouse strawberry crop grown in north-central Florida.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Nov-Mar
Yield (kg/m^2)[z]	T[w]	0.44	2.64	2.86	3.08	1.98	End						11.00
Yield (% of total)[z]		4	24	26	28	18							100.00
Price ($/kg)[y]	1.98	2.76	3.81	3.08	2.62	2.10	1.77	1.66	1.76	1.60	1.83	1.75	2.87[v]
Price ($ per flat)[y]	9.42	13.14	18.16	14.71	12.48	10.03	8.47	7.92	8.39	7.64	8.72	8.33	13.71[v]
Revenue ($/m^2)[x]		1.21	10.05	8.82	8.06	4.16							32.31

[z]Monthly fruit yields estimated from experimental crops grown in a passively ventilated greenhouse at the UF Protected Ag Project, Gainesville, FL.
[y]F.O.B. shipping point average prices for medium-large grade strawberries (12, 0.5-L baskets or eight, 0.6-kg clamshells per flat): (1993-2002)/USDA-AMS.
[x]Gross revenue.
[w]Transplanting plugs: 1 Oct; harvest period: Nov-Mar; termination: 1 Apr.
[v]Mean for the harvest period Nov-Mar. The annual mean was $2.23/kg or $10.62 per 4.77-kg flat.

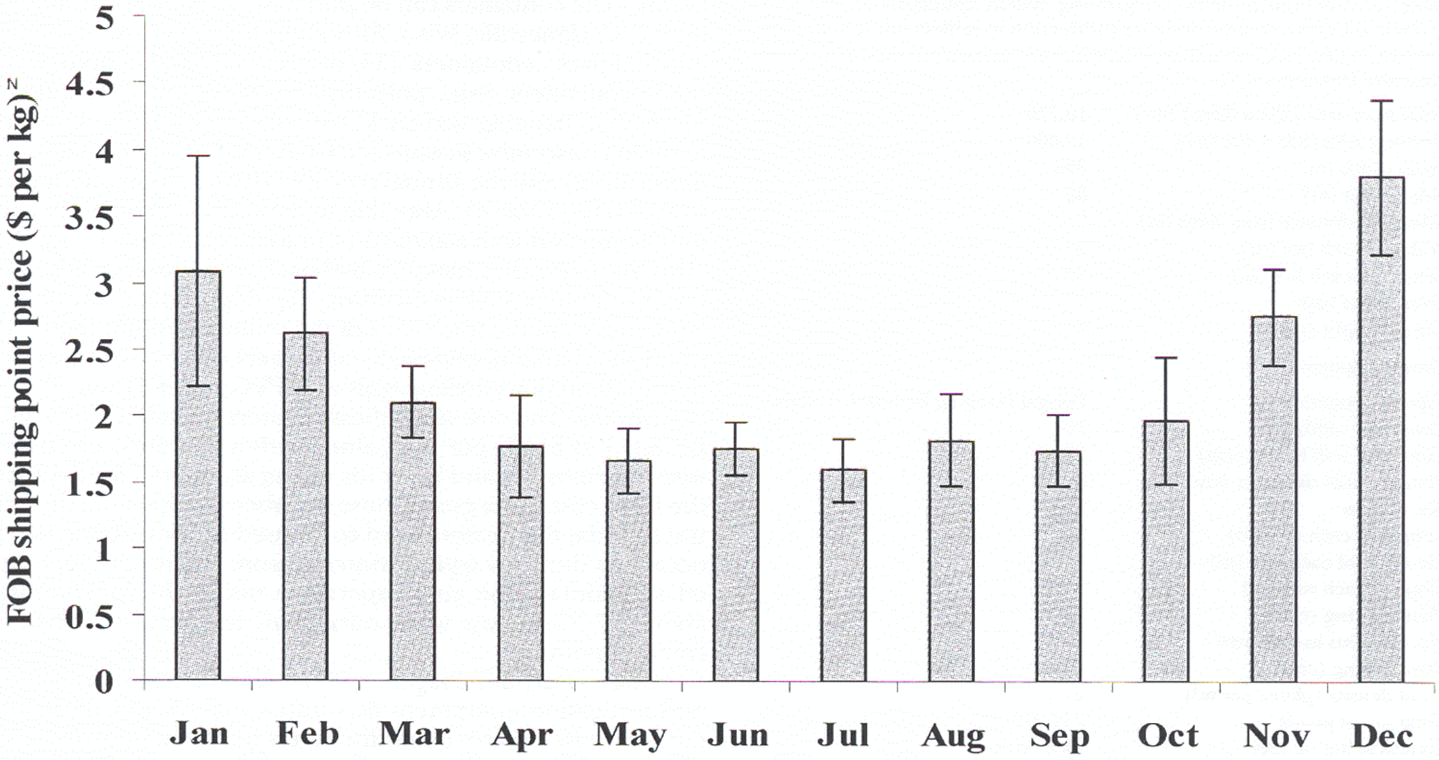

Fig. 3. Average F.O.B. shipping point strawberry prices per kg (1993-03).
[z]Average F.O.B. shipping point prices per kg of strawberries: (1993-2002) USDA-AMS. Bars represent standard error.

pests such as whiteflies and thrips, and also help in retaining bumblebees within the growing area. Roof vents and the side curtains can be opened or closed with the help of gear motors for temperature regulation.

Greenhouse construction. Labor cost and cost of equipment needed for greenhouse construction accounted for a major share (32.1%) of the fixed cost. Estimated labor cost for land preparation (including rental equipment) was $3/m², and

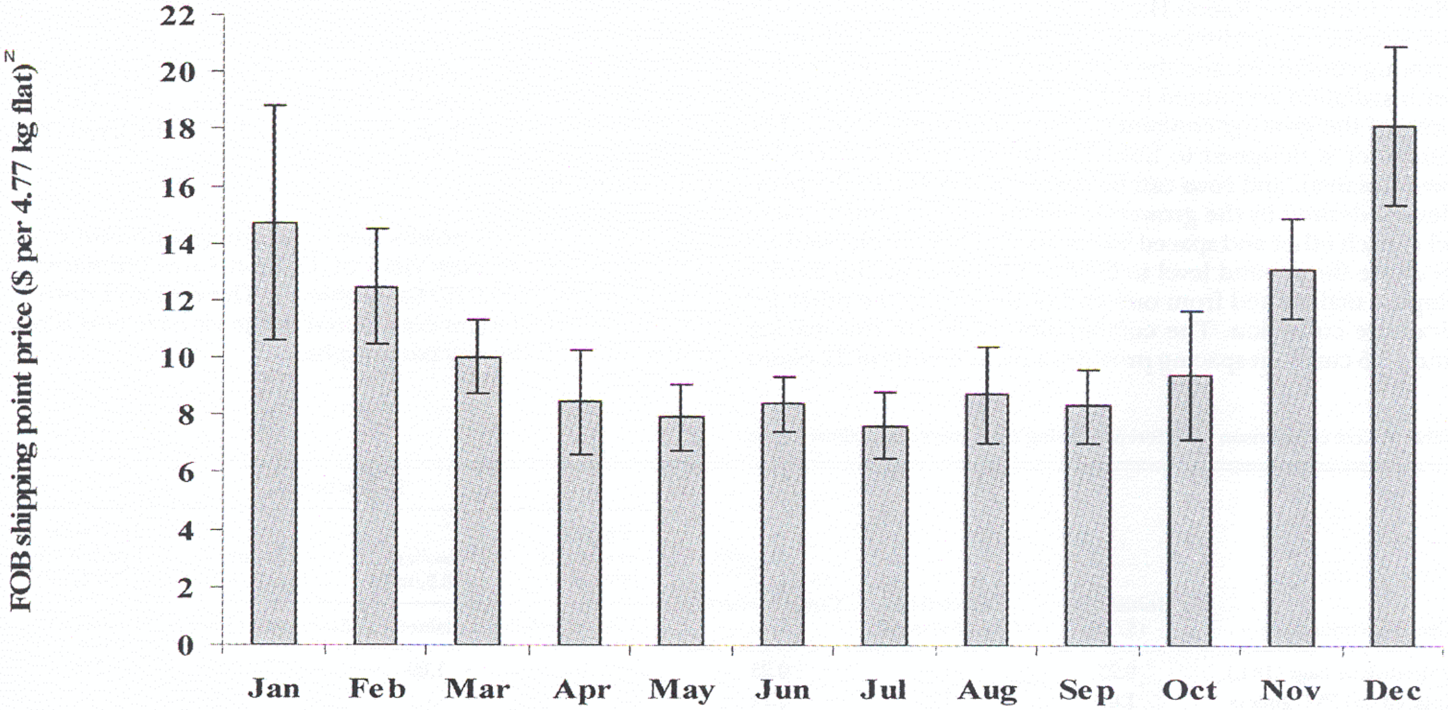

Fig. 4. Average F.O.B. shipping point strawberry prices per 4.77-kg flat (1993-03).
[z]Average F.O.B. shipping point prices for strawberry flats containing 12, 0.5-L baskets or eight, 0.6-kg clamshells: (1993-2002) USDA-AMS. Bars represent standard error.

Table 2. Structural dimensions, growing system configuration, and crop cycle for greenhouse strawberry production in soilless substrate.

Structure Dimensions	
Total floor area [335 × 32 m] (m^2)	10,720
Growing area [333 × 30] (m^2)	10,000
Front width (m)	335
Side length (m)	32
All-round distance from sides (m)	2
Width of each bay (m)	9
Length of each bay (m)	30
Total no. of bays	7
Gutter height (m)	4
Growing System	
Type of container	Polygal Hanging Bed-pack troughs
Container width (cm)	10
Container wall height (cm)	12
Planting hole diameter (cm)	5
No. of rows	740
Length of each row (m)	30
Elevation of each row (m)	1.8
Slope of each row (%)	0.5
Plant spacing (cm)	17.5
No. of plants in each row	330
Row spacing (cm)	45
Plant density (plants per m^2)	24.4
Total no. of plants	244,000
Soilless substrate used	Pine bark
Crop Cycle	
Planting date	Oct 1
Days to first harvest	45
Harvest period	Nov 15-Mar 31

the labor cost for erecting the greenhouse was estimated at $14.42/m².

Growing system. 'Hanging bed-pack' containers (Polygal Plastic Industries, Ramat Hashofet, Israel), designed especially for strawberry production were used in this study. Cost of growing containers, and the cost of material and labor needed for installation accounted for 14.5% of the fixed cost. Dimensions of the growing container are presented in Table 2. The container is designed to hold 11 plants per m (17.5 cm between plants), and rows can be spaced according to the plant density desired by the grower. Containers are arranged parallel to each other and spaced 50 cm apart. They are elevated 1.8 m above the ground level to facilitate harvesting, and a 0.5% slope is maintained from one end of the row to the other for drainage collection. The combination of 50 cm row-spacing and 17.5 cm plant-spacing provides a plant density of 22 plants per m². The containers can be purchased in the U.S. from Polygal USA (Janesville, Wis.). Although the initial cost of 'hanging bed-pack' containers ($3/m) is higher compared with other containers (e.g., polyethylene bags with PVC gutter: $1.25/m), 'hanging bed-pack' containers can be used for up to seven consecutive seasons (N. Gnayem, 2003, personal communication) and the annual cost after depreciation is reduced to $0.43/m (Table 4). Also, due to their smaller container volume compared with standard (1 m long × 0.21 m wide) polyethylene bags, the 'hanging bed-pack' containers hold 33% lesser volume of soilless medium. The depreciated cost of the containers and the lower cost of the soilless medium required to fill the 'hanging bed-pack' containers makes them less expensive than polyethylene bags with PVC gutter (Table 3).

Heating. The cost of 16 diesel heaters (Sundair, Inc., Baltic, S.D.) at $1400 per unit, along with a fuel tank, electrical wire, thermostats, and labor for wiring accounted for 8.4% of the fixed cost. For a greenhouse strawberry crop in north-central Florida, the heaters need to be used only on about 10-14 occasions during a typical winter season. Heaters are operated to maintain the air temperature inside the greenhouse above 5-7 °C on days when outside air temperature is below freezing point.

Water supply and fertigation. The cost of water supply lines and fertigation equipment accounted for 3.5% of the fixed cost. It is essential to install disc filters on the main water supply line to ensure smooth functioning of fertilizer injectors and to prevent clogging of drip irrigation lines. The irrigation controller can schedule irrigations based on a pre-set program, or, it can deliver irrigations in real time based on the solar radiation.

Moving equipment. This includes 12, four-wheeled carts designed to aid in harvesting and to move strawberry flats from the greenhouse to the loading dock, and a forklift, which is used for loading pallets from the loading dock into the refrigerated truck. The cost of the moving equipment accounted for 2.9% of the fixed cost.

Miscellaneous and office equipment. The cost of miscellaneous equipment such as weighing scales, pH, E.C., NO^{3-} and K^+ meters, and office equipment such as computers, furniture, fax and copy machines, etc. accounted for 2.3% of the fixed cost.

Variable Costs

The variable (or production) cost for greenhouse strawberries with an average yield of 11 kg m^{-2} was estimated at $20.91/m² or $209,075/ha (Table 5). The cost and description of individual items considered in the variable cost is presented in the following paragraphs:

Table 3. Cost comparison of different growing containers and soilless media.[z]

				Soilless media			
				2 peat + 1 perlite mix ($55/m³)	Pinebark ($8.5/m³)	Perlite ($40.7/m³)	2 coco-coir + 1 perlite mix ($36.4/m³)
Growing container	Initial cost ($/m)	Expected life (No. of seasons)	Cost per season ($/m)	Cost of growing container + soilless media ($ per m² per season)			
Polyethylene bags (18 L)	0.25	1	0.25	2.76	1.09	2.25	2.09
(placed on) PVC gutters	1.00	7	0.14				
Polygal troughs (12 L)	3.00	7	0.43	2.18	1.06	1.84	1.66

[z]All calculations are based on two, 1-m rows of polyethylene bags or troughs per m² of greenhouse space.

Table 4. Estimated fixed costs and annual depreciation for 1 ha passively ventilated greenhouse.

Item	Original cost ($/ha)	Original cost ($/m²)	Projected life (years)	Depreciation[y] ($/ha)	Depreciation[y] ($/m²)
Greenhouse structure (33.1%)[z]					
Galv. pipes, joints, Al grippers, gutters, access gates, etc.	140,000	14.00	10	14,000	1.40
Electric motors, gear assembly for side curtains & roof-vents	25,000	2.50	10	2,500	0.25
Ocean freight + Insurance	10,000	1.00	10	1,000	0.10
Office/warehouse (10 × 10 m)	15,000	1.50	10	1,500	0.15
	190,000	**19.00**		**19,000**	**1.90**
Greenhouse coverings (3.2%)[z]					
Polyethylene cover for roof & side-walls	13,000	1.30	3	4,333	0.43
Insect proof netting (all openings)	5,500	0.55	10	550	0.06
	18,500	**1.85**		**4,883**	**0.49**
Greenhouse construction (32.1%)[z]					
Site preparation (leveling, compaction)	30,000	3.00	10	3,000	0.30
Supervision 20 days + airfare	10,000	1.00	10	1,000	0.10
Labor for erecting the greenhouse	144,184	14.42	10	14,418	1.44
	184,184	**18.42**		**18,418**	**1.84**
Growing system (14.5%)[z]					
Hanging bed-pack troughs (19,980 m) [666 rows, each 30 m long, spaced 50 cm apart]	59,940	5.99	7	8,563	0.86
Materials to set up growing system (steel wire, etc.)	3,500	0.35	7	500	0.05
Labor to set up & hang the growing system (based on 4 h per 30 m long row @ $7.50/h)	19,980	2.00	7	2,854	0.29
	83,420	**8.34**		**11,917**	**1.19**
Heating (8.4%)[z]					
Diesel heaters (16 units)	22,400	2.24	10	2,240	0.22
Fuel tank for heaters (11,000 L)	6,500	0.65	10	650	0.07
Electrical fittings, thermostats, cables	6,200	0.62	10	620	0.06
Labor for wiring	12,800	1.28	10	1,280	0.13
	47,900	**4.79**		**4,790**	**0.48**
Water supply (2.3%)[z]					
PVC fittings, pressure gauges, filters, etc.	7,000	0.70	10	700	0.07
Labor for plumbing water supply lines	6,000	0.60	10	600	0.06
	13,000	**1.30**		**1,300**	**0.13**
Fertigation (1.2%)[z]					
Injector, filters, PVC fittings, solenoid valves	4,000	0.40	10	400	0.04
Irrigation controller	3,000	0.30	6	500	0.05
	7,000	**0.70**		**900**	**0.09**
Moving equipment (2.9%)[z]					
Forklift	12,000	1.20	8	1,500	0.15
Carts for harvesting and moving materials (12 units)	4,800	0.48	8	600	0.06
	16,800	**1.68**		**2,100**	**0.21**
Misc. equipment (0.9%)[z]					
Tools, scales	3,000	0.30	3	1,000	0.10
ph & EC meter, NO_3 & K meter	2,000	0.20	3	667	0.07
	5,000	**0.50**		**1,667**	**0.17**
Office equipment (1.4%)[z]					
Computer, copy machine, printer and fax machine	5,000	0.50	4	1,250	0.13
Office furniture & stationery	3,000	0.30	4	750	0.08
	8,000	0.80		2,000	0.20
Total investment	**573,804**	**57.38**		**66,976**	**6.70**

[z]Percent of total fixed cost.
[y]Depreciation = Original cost ÷ Expected Life (years).

Table 5. Estimated variable costs for 1 ha greenhouse strawberry enterprise.

Item	Unit	Quantity	Price ($/unit)	Total $/ha	Total $/m²
Plants (14.7%)[z]					
Strawberry plug transplants (22 plants per m² or 220,000 plants per ha)	ea.	220,000	0.14	30,800	3.08
				30,800	**3.08**
Soilless medium (1.0%)[z]					
Pine bark	m³	240	8.50	2,040	0.20
				2,040	**0.20**
Irrigation (0.8%)[z]					
Drip tape (5 cm emitter spacing)	m	19,980	0.08	1,598	0.16
Polypipe (3/4 inch), fittings, etc.	m	1000	0.15	150	0.02
				1,748	**0.17**
Beneficials (biological control insects and pollinators) **(5.8%)**[z]					
Neoseiulus californicus predatory mites (ten mites per m² × four releases)	1000/bottle	400 bottles	7.50	3,000	0.30
Aphidius colemani parasitic wasps (five wasps per m² × three releases)	5000/bottle	30 bottles	145	4,350	0.44
Amlysieus cucumeris predatory mites (ten mites per m² × three releases)	50,000/bottle	6 bottles	38	228	0.02
Bombus impatiens (Class-A bumblebee hives)	100 bees/hive	12 hives	210	2,520	0.25
Shipping (predatory mites, wasps, ladybeetles, and bumblebees)				2,000	0.20
				12,098	**1.21**
Fertilizer (1.6%)[z]					
(0.06 g fert. or nutrient soln. at 150 ml per plant per day × 180 d)	kg	2376	1.4	3,326	0.33
				3,326	**0.33**
Energy (4.1%)[z]					
Propane gas (for forklift)				2,000	0.20
Diesel for heaters (80 L per heater per night × ten nights)	liters	12,800	0.40	5,120	0.51
Electricity	kWh	15,000	0.10	1,500	0.15
				8,620	**0.86**
Packing material, cooling, and shipping (47.3%)[z]					
Flat with eight, 0.6-kg clamshells (for packing 44,000 kg strawberries)	flat	12,088	2.00	24,176	2.42
Flat with 12, 0.5-L baskets (for packing 66,000 kg strawberries)	flat	13,837	1.00	13,837	1.38
Pre-cooling	flat	25,925	0.75	19,444	1.94
Freight	flat	25,925	0.60	15,555	1.56
Brokerage (8% of gross revenue: 0.08 × $323,100)[z]				25,848	2.58
				98,860	**9.89**
Labor (24.7%)[z]	Hours	Times	Total hours		
Filling growing system with soilless media (10 s/m)	56	1	56	420	0.04
Cleaning growing system at end of season (10 s/m)	56	1	56	420	0.04
Planting strawberry transplants (allowing 7 s per plant)	428	1	428	3,210	0.32
Scouting (7 h/wk × 24 wks)	7	24	168	1,680	0.17
Releasing *N. californicus* predatory mites (3 min per 1000 mites)	5	5	25	188	0.02
Releasing *A. colemani* parasitic wasps (3 min per 1000 wasps)	5	3	15	113	0.01
Releasing *A. cucumeris* predatory mites (3 min per 1000 mites)	5	3	15	113	0.01
Mixing fertilizer (allowing to mix one batch per week × 24 weeks)	8	24	192	1,440	0.14
Harvesting strawberries (110,000 kg) (1,833 kg per harvest × 60 harvests)[y]	96	60	5760	44,000	4.40
				51,583	**5.16**
Total variable cost				**209,075**	**20.91**

[z]Percent of total fixed cost.
[y]Gross revenue based on estimated monthly yields and monthly F.O.B prices presented in Table 1.
[x]Estimated total yield: 500 g per plant (54% of total, i.e., 270 g per plant from Nov-Jan; and 46% of total, i.e., 230 g per plant from Feb-Mar). Estimated total yield based on data obtained from greenhouse trials conducted in north-central Florida from 2000-2003.

Plants. The cost of plug transplants accounted for 14.7% of the variable cost. In greenhouse strawberry culture, plug transplants are preferred over bare-root transplants. Plug transplants ($0.14 ea.) are more expensive than bare-root transplants ($0.07 ea.), but plug transplants establish quickly, do not need overhead irrigation for establishment, are more uniform, and produce higher early yields. Moreover, plugs have a reduced risk of soil-borne diseases since they are produced in inert (soilless) plug-mixes, and can be artificially pre-conditioned if necessary to enhance early yields. Generally, it is desirable to use three to four different cultivars so that the risk of yield losses due to failure of any one cultivar is minimized, and a more uniform production curve can be maintained since different cultivars may have different peaks of production. For example, a combination of 'Carmine' and 'Treasure', which produce high early yields, along with 'Strawberry Festival' and 'Camarosa', which produce high yields during mid and late season, may ensure a steady supply of strawberries throughout the growing season.

Soilless medium. The soilless medium in which plants are grown is an important consideration since plant growth and yield can be significantly influenced by the type of soilless medium. Previous studies (Paranjpe, 2003) have indicated that early yields obtained from plants grown in peat-mix, perlite, or pine bark were similar. From an economic standpoint, pine bark ($8.50/m^3) is six times less expensive than peat-mix ($55/m^3), and about five times less expensive than perlite ($40.70/m^3) (Table 3). Also, pine bark is locally available in Florida and handling and disposal are easy. In the present study, the cost of pine bark used in strawberry production accounted for 1% of the variable cost. If either peat-mix or perlite is used, their cost can account for up to 5% and 3.8% of the variable cost, respectively.

Irrigation and fertilizer. The cost of irrigation materials (drip tape, polypipe, fittings) and the cost of the fertilizer accounted for 0.8% and 1.6% of the variable cost, respectively. Drip tape (Chapin Watermatics, Watertown, N.Y.) used for irrigating the strawberry plants had a 5-cm emitter spacing and a discharge rate of 9.5 mL min^{-1}. Nutrient requirement of strawberry plants is relatively low compared with other greenhouse crops such as bell peppers, cucumbers, or melons. Strawberry plants need an estimated quantity of 0.06 g of fertilizer (or complete nutrient solution) per plant per day, which includes all macro- and micro-elements necessary for normal plant growth. Fertilizer is comprised of 12 nutrients (N, P, K, Ca, Mg, S, Fe, Zn, Mn, Cu, Mo), and a fresh batch is mixed once per week.

Beneficials. The present feasibility study is done for producing 'pesticide-free' strawberries by managing the pests exclusively with predatory or parasitic insects (beneficials) that occur naturally or are sold commercially. Scientific names, quantities, and costs of beneficial insects, and labor costs for scouting and releasing beneficial insects are presented in Table 5. In protected strawberry culture, it is absolutely essential to use bumblebees for pollination, since the influence of natural agents such as wind, insects, etc. that help pollination of strawberry flowers in the open fields is greatly reduced under protected culture. Total cost of beneficial insects needed for controlling insect pests and the cost of bumblebees accounted for 5.8% of the variable cost. Although this cost may be substantially higher compared with much lower costs of chemical pest management, the use of beneficial insects may be justified if 'pesticide-free' strawberries can be sold at a premium price. Besides improving product quality (by reducing or eliminating pesticide usage), biological pest management becomes inevitable in greenhouse strawberry production since chemical pesticides may not provide satisfactory pest control (as pests may develop resistance to chemicals), are harmful to bumblebees, and almost invariably have a re-entry interval of at least 1 d, which may reduce harvest efficiency. Thus, in terms of improving fruit quality, worker safety, harvest efficiency, and product value, biological pest management can be a better option compared with chemical control.

Energy. Cost of diesel fuel needed for heating purposes, cost of propane needed for operating the forklift, and electricity needed for operating roof-vents and side curtains accounted for 4.1% of the variable cost. Fuel cost for heating a passively ventilated greenhouse located in a region with mild winter climate is substantially lower than the fuel cost of heating greenhouses located in colder regions. Also, the amount of electricity consumed for cooling passively ventilated greenhouses is significantly reduced since these greenhouses do not use pads and electric fans for cooling.

Packing material, pre-cooling, brokerage. Total cost of packing material, pre-cooling, freight, and brokerage was substantial, and accounted for 47.3% of the variable cost. Packing material includes 0.6-kg plastic clamshells with lids, 0.5-L plastic baskets, and cardboard flats that can hold eight clamshells or twelve baskets. Strawberries are a highly perishable commodity and need to be pre-cooled to 1 °C as soon as they are harvested. Typically, most strawberries reach the consumer (or the retail market) within 36 h from the time of harvest. Brokerage can range between 8-10% of the sales value, and may vary depending on market prices and business relationships.

Labor. Total labor cost for all cultural operations (filling soilless media in to containers, cleaning the containers, planting, scouting, releasing beneficial insects, and harvesting) accounts for 24.7% of the variable cost. However, the labor cost of harvesting alone represents 20% of the variable cost. A description of the labor activities needed for different cultural operations is provided in the following paragraphs:

a. *Filling pine bark in growing containers/cleaning at the end of the season.* In the last week of September, aged pine bark (6.5 cm^2 sieved) is added to the growing containers up to the level of the planting holes. At the end of the season, the root mass along with the pine bark are removed and gutters are cleaned with a 1% bleach solution.

b. *Planting.* In the first week of October, strawberry plug plants (2-2.5 months old) are transplanted into each planting hole, and more pine bark is added so that the root ball is covered. It is important to ensure that the drip tape is above the root ball and not under it.

c. *Harvesting.* In Florida, strawberries are harvested from the second week of November until the end of March. The date of terminating the harvest mainly depends on the market price, and strawberry growers in west-central Florida generally continue picking until the market price stays above $5.50-$6.50 per flat. Harvesting is generally done at 2-3 d intervals. In this study, it is assumed that one person can harvest approximately 160 kg of strawberries in an 8-h day, and wages for harvesting strawberries are calculated at $7.50/h or $0.40/kg. Harvesting of stem-berries is a slower process, and one person may be able to harvest only 60-70 kg per 8-h day. However, the market price of stem berries is generally twice that of regular berries.

d. *Scouting and releasing beneficial insects.* This is an important activity since the success of a biological pest management program depends mainly on the ability of the scout to detect pests early and release the appropriate beneficial insects to control the pests. For example, the orders for beneficial insects such as *Aphidius colemani* may need to be placed 1 week in advance, whereas the predatory mites can generally be obtained overnight. Biological pest management is a specialized job, and in the present study, the person in charge is paid a higher wage of $10/h.

e. *Net revenue.* After accounting for annual depreciation cost and variable cost, the net revenue (Table 6) above total annual cost was $3.77/m² or $37,749/ha, based on an average yield of 11 kg m^{-2} and the average monthly market prices presented in Table 1.

f. *Sensitivity analysis.* The sensitivity analysis illustrates variations in net returns as dictated by a range of possible marketable yields and market prices (Tables 7 and 8). As marketable yields and market prices increase, variable cost increases since labor cost for harvesting, cost of packing material, pre-cooling, transportation, and brokerage expenses also increase. However, fixed cost can also change considerably according to the choice of equipment, geographical location, and personal skills. Therefore, two separate sensitivity analyses are presented: (a) Net returns obtained above variable (or production) cost, and (b) Net returns obtained above total cost (depreciation on fixed cost + variable cost). Effect of different yields and market prices on the variable cost and corresponding increase or decrease in net revenue above variable cost (returns to management) is presented in Table 7. A minimum yield of 7 kg m^{-2} and an average market price of $9.83 per flat ($2.06/kg) are needed for breaking even with the variable cost. At an average yield of 11 kg m^{-2}, a minimum market price of $8.24 per flat ($1.73/kg) will be needed to break even with the variable cost.

Similarly, as marketable yields and market prices increase or decrease, the total cost (variable cost + depreciation on fixed cost) of greenhouse strawberry production will increase or decrease. The effect of different yields and market prices on the total cost (depreciation on fixed cost + variable cost) and the corresponding increase or decrease in net revenue above the total cost (returns to capital) is presented in Table 8. A minimum yield of 7 kg m^{-2} and an average market price of $14.98 per flat ($3.14/kg) are needed for breaking even with the variable cost. With an average marketable yield of 11 kg m^{-2}, a market price of $11.55 per flat ($2.42/kg) will be necessary to break even with the total cost.

Table 6. Enterprise budget for strawberry production in a 1-ha greenhouse in Florida.

Item	Unit	Quantity	Price ($/unit)	Total ($/ha)	Total ($/m²)
(A) Gross revenue	kg	110,000	2.37-4.64[z]	**323,100**	**32.31**
(B) Fixed cost					
Depreciation				66,976	6.70
Other fixed costs				9,300	0.93
Total (B)				**76,276**	**7.63**
(C) Variable cost					
Preharvest costs					
Plants	ea.	220,000	0.14	30,800	3.08
Soilless medium	m³	240	8.5	2,040	0.20
Irrigation				1,748	0.17
Beneficials & pollinators				12,098	1.21
Fertilizer	kg	2,376	1.4	3,326	0.33
Diesel fuel	L	12,800	0.4	5,120	0.51
Electricity	kWh	15,000	0.1	1,500	0.15
Propane				2,000	0.20
Labor	h	955	7.5	7,583	0.76
Sub-total (preharvest cost)				**66,215**	**6.62**
Harvest costs					
Labor	h	5760	7.5	44,000	4.40
Packing material (flats with eight, 1-lb clamshells)	ea.	12,088	2	24,176	2.42
Packing material (flats with 12, 1-pt baskets)	ea.	13,837	1	13,837	1.38
Pre-cooling	flat	25,925	0.75	19,444	1.94
Freight	flat	25,925	0.6	15,555	1.56
Brokerage	%	323,100	8	25,848	2.58
Sub-total (harvest cost)				**142,860**	**14.29**
Total (C)				**209,075**	**20.91**
Total annual cost {(B) + (C)}				**285,351**	**28.54**
Net revenue above total cost				**37,749**	**3.77**

[z]Range of average monthly F.O.B. shipping point prices per kg (Nov-Mar) for medium-large grade strawberries packed in 12, 1-pt baskets (1993-2002)/ USDA-AMS.

Table 7. Production costs per m² and net returns above production cost (returns to management) for 1-ha greenhouse strawberry enterprise calculated for a specified range of marketable yields and F.O.B. shipping point prices.

Yield	Prod. cost	F.O.B. shipping point prices ($/kg)[z]							
		1.57 (7.50)	1.99 (9.50)	2.20 (10.50)	2.41 (11.50)	2.62 (12.50)	2.83 (13.50)	3.04 (14.50)	3.25 (15.50)
(kg/m²)	($/m²)	Net returns above variable cost ($/m²)							
7	14.38	-2.01	1.29	2.94	4.59	6.24	7.89	9.54	11.19
8	15.54	-1.40	2.37	4.26	6.15	8.03	9.92	11.80	13.69
9	16.69	-0.79	3.46	5.58	7.70	9.82	11.94	14.06	16.18
10	17.85	-0.18	4.54	6.90	9.25	11.61	13.97	16.32	18.68
11	19.01	0.44	5.62	8.21	10.81	13.40	15.99	18.58	21.17
12	20.16	1.05	6.71	9.54	12.36	15.19	18.02	20.85	23.68
13	21.32	1.66	7.78	10.85	13.91	16.98	20.04	23.10	26.17
14	22.48	2.27	8.87	12.16	15.46	18.76	22.06	25.36	28.66

[z]Numbers in parenthesis are F.O.B. shipping point prices ($ per 4.77-kg flat).

Table 8. Total costs per m² and net returns above total cost[z] (returns to capital) for a 1-ha greenhouse strawberry enterprise calculated for a specified range of marketable yields and F.O.B. shipping point prices.

Yield	Total cost[y]	F.O.B. shipping point prices ($/kg)[z]							
		1.57 (7.50)	1.99 (9.50)	2.20 (10.50)	2.41 (11.50)	2.62 (12.50)	2.83 (13.50)	3.04 (14.50)	3.25 (15.50)
(kg/m²)	($/m²)	Net returns above total cost ($/m²)[y]							
7	22.01	-9.63	-6.33	-4.68	-3.04	-1.39	0.26	1.91	3.56
8	23.16	-9.02	-5.25	-3.37	-1.48	0.40	2.29	4.17	6.06
9	24.32	-8.41	-4.17	-2.05	0.07	2.19	4.31	6.43	8.56
10	25.48	-7.80	-3.09	-0.73	1.62	3.98	6.34	8.69	11.05
11	26.64	-7.19	-2.01	0.59	3.18	5.77	8.36	10.95	13.55
12	27.79	-6.58	-0.92	1.91	4.74	7.56	10.39	13.22	16.05
13	28.95	-5.97	0.16	3.22	6.28	9.35	12.41	15.48	18.54
14	30.11	-5.36	1.24	4.54	7.84	11.14	14.44	17.74	21.03

[z]Numbers in parenthesis are F.O.B. shipping point prices ($ per 4.77-kg flat).
[y]Total cost = (annual depreciation on fixed cost + variable cost).

Conclusions

This economic feasibility study has shown that greenhouse strawberry production in a high-roofed, passively ventilated greenhouse can be considered as an economically viable alternative to conventional field strawberry production in Florida.

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