HORTSCIENCE 32(6):1126–1129. 1997.

Assessing the Economic Efficiency of a Soilless Culture System for Off-season Strawberry Production

K. Mattas[1]
Department of Agricultural Economics, Aristotle University of Thessaloniki, P.O. Box 225, 540 06 Thessaloniki, Greece

M. Bentes[2]
Mediterranean Agronomic Institute, P.O. Box 85, 731 00 Chania, Greece

G. Paroussi[3]
Agricultural Research Center of Northern Greece, P.O. Box 312, 570 01 Thermi, Thessaloniki, Greece

I. Tzouramani[4]
Department of Agricultural Economics, Aristotle University of Thessaloniki, P.O. Box 225, 540 06 Thessaloniki, Greece

Additional index words. *Fragaria ×ananassa*, greenhouses, economic evaluation, Greece

Abstract. **The financial effectiveness of a soilless vertical bag system of hydroponics culture was evaluated for off-season strawberry (*Fragaria ×ananassa* Duch) production in heated greenhouses in northern Greece. Financial analysis revealed that the implementation of this soilless culture system instead of the traditional production system under plastic tunnels would not be profitable for Greek farmers due to its high initial investment and high fuel consumption. Sensitivity analysis indicated the importance of product price in affecting the magnitude of benefits, confirming the interest of farmers to produce off-season strawberries to market them when prices are likely to be higher. In addition, yield increase will have a positive effect upon farmers' income.**

Over the past two decades, greenhouse production of high-value horticultural crops has expanded considerably. The prospects for greenhouse cultivation have changed radically by moving away from soil cultivation to isolated, soilless growing systems (Hall et al., 1988). In addition, the constant increase in demand for off-season products encourages farmers to produce vegetables under protected systems of cultivation by introducing new techniques (Mittider et al., 1982).

In Greece, 11,000 ha are occupied by plastic greenhouses and high tunnels for various vegetables and strawberries. Strawberries are generally grown either outdoors or under cover (greenhouses or plastic tunnels). The greenhouse production period starts in November and continues throughout May, with a peak in March. Production from plastic tunnels is concentrated in April and May, while the open field production extends from May to June. Generally, early production coming from greenhouses or plastic tunnels is sold at very high prices compared with that sold in May or June.

Farmers have tried various techniques of greenhouse production, one of them being vertical cultivation, to gain higher income. Vertical cultivation is considered potentially useful, mainly because it makes for better energy utilization and more efficient use of the greenhouse volume, resulting in a higher yield per unit area than with conventional culture. The new technique requires a thorough investigation of the economic efficiency of the technique before growers supplant traditional techniques with the new one.

Our study attempts to evaluate the financial effectiveness of strawberry cultivation in heated greenhouses using a soilless culture system (SCS), specifically, the vertical bag system of hydroponics culture, for off-season production in northern Greece. The main objective of the research reported in this study is to assess the profitability and limitations of the application of the SCS to develop strategies that growers should follow for best economic results. Therefore, production and gross returns for SCS and the traditional production system (TPS) under plastic tunnels were evaluated and compared. The magnitude of the benefits provided by the technologies was estimated and compared using the appraisal criteria of net present value (NPV) (inflation adjusted model), internal rate of return (IRR), benefit/cost (B/C) ratio, payback period (PP), and discounted payback period (DPP). Furthermore, factors affecting the magnitude of the income benefits were identified and investigated by performing sensitivity analysis.

Materials and Methods

Data. Data for SCS were obtained mainly from experiments conducted at the Agricultural Research Center of northern Greece in the region of Thessaloniki. Also, variable production costs were estimated using unpublished data. Fixed production costs were obtained from Salem et al. (1993) for the heating system and from Tzouramani et al. (1995) for greenhouse construction. Strawberry market prices were obtained from the Sindos Wholesale Market (Thessaloniki). The experiments were conducted during 1992–93 and 1993–94. The cultivars Brighton and Selva were used in 1992–93; 'Brighton' was replaced with 'Fern' in 1993–94.

A round, arch-type polyethylene-covered greenhouse with vertical side walls (single span) was used (Tzouramani et al., 1995). It had a double roof, automatically operated sidewall openings and a south–north orientation. Heating was with warm air originating from a central diesel boiler (diesel-fired furnace system; DFS) (Salem et al.,1993), and an automatic thermostatic system controlled high temperatures by ventilation. The greenhouse area was 200 m^2. The ground was covered with white plastic sheeting to ensure light reflection for the plants at the bottom of the vertical bags and to control the weeds.

In 1992–93, the sprigs were planted on 20 Aug. in a mixture of perlite (8%) and turf (20%). They were transplanted to vertical plastic bags filled with perlite. In 1993–94, the sprigs were planted on 2 Sept. The plants and perlite were renewed every crop season.

Strawberry plants were transferred to vertical plastic bags made of white polyethylene tubes, 2 m high and 16 cm in diameter, filled with agricultural perlite. The bags were spaced at intervals of 0.80×1.0 m, ≈1000 bags/0.1 ha. Twenty-four plants were planted along the side of each bag, from the bottom to the top in four vertical rows, resulting in a total of ≈24,000 plants/0.1 ha. Metal beams were used to support the bags (Paraskevopoulou-Paroussi et al., 1995).

Nutrient solution was released with two drippers, each having a capacity of 4 $L \cdot h^{-1}$, through feeding pipes into the upper and middle part of the bags. Holes in the bottom of the bags allowed the solution to be drained into a tank to be tested and, if necessary, corrected with supplementary fertilizer. The storage tanks, with a 1-ton capacity, were placed inside the greenhouse (Paraskevopoulou-Paroussi et al., 1995).

Data for TPS were selected by the Agricultural Research Center of northern Greece from growers cultivating strawberries in high tunnels (2 m in height), employing the double-row system on beds. The plants were planted 30 cm apart in two rows on the top of a bed that was 20 cm high and mulched with black polyethylene. Each level bed was 60 cm wide. The

Received for publication 22 Jan. 1997. Accepted for publication 10 Feb. 1997. We gratefully acknowledge valuable comments and suggestions by two anonymous journal reviewers and the editor. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.
[1]Professor.
[2]MSc.
[3]Researcher.
[4]PhD Student.

Table 1. Average annual total and marketable strawberry production (kg) and average annual gross returns (Drs)[z] referred for the soilless (SCS) and traditional (TPS) production systems, 0.1 ha. (Thessaloniki, Greece, 1994).

Criterion	Fruit production	System TPS	System SCS
Annual average production	Total	3.00	7.21
(kg, 1000s)	Marketable	3.00	5.86
Gross returns	Total	1.140	4.991
(Drs, millions)	Marketable	1.140	4.183

[z]All prices are expressed as 1994 drachmas (Drs; 1 U.S. dollar = 250 Drs).

beds were spaced 50 cm apart and drip irrigation was used.

Method of economic assessment. Several approaches have been used to evaluate the adoption of a new technique. For Gittinger (1972), the concept underlying economic and financial analysis of alternative projects is that costs and benefits "with" and "without" the investment must be compared to determine which alternative gives a higher return. Under this approach, the main advantage is that only costs or benefits that change are recorded. This analysis employs several alternative techniques: NPV, IRR, B/C, PP, and DPP. According to Brigham (1985), NPV is the value of the expected net cash flows of an investment discounted to an appropriate percentage. This concept, Eq. [1], can be written in a general form:

$$NPV = \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t} 2 \qquad [1]$$

where CF_t = net cash flow in year t, r = the appropriate discount rate, and T = the project's expected life.

An investment project will be deemed acceptable if the sum of the discounted net benefits (benefits minus costs) is positive.

In an inflationary environment, the NPV expression is based on Eq. [2], introduced by Bartley (1980), and modified for use with the problem under investigation:

$$NPV = \sum_{t=1}^{8} \frac{\left[IF_t \prod_{j=1}^{t}(1+u_j)\right] - \left[OF_t \prod_{j=1}^{t}(1+v_j)\right]}{(1+r)^t \prod_{j=1}^{t}(1+i_j)} \qquad [2]$$

where IF_t = expected cash inflow in year t, OF_t = expected cash outflow in year t, u_j = anticipated inflation rate for cash inflows in period j, v_j = anticipated inflation rate for cash outflows in period j, i_j = anticipated inflation rate for general price level in period j, and r = risk-adjusted discount rate.

The steps that need to be followed in evaluating the adoption of a new technique can be outlined as follows (Food and Agriculture Organization of the United Nations, 1995): 1) Changes either in costs or in benefits due to implementation of the technique have to be identified. 2) The identified costs and benefits must be measured and compared (incremental analysis) by expressing them at a particular time point (preferably in current prices for the year of implementing the technique). 3) The effectiveness of the technique is judged by estimating a measure of project worth (NPV).

We first identified, priced, and valued expected costs and benefits for SCS and TPS. Next, we applied incremental analysis for benefits and costs to compare these results from SCS with those from TPS. In addition, net cash flow was identified (incremental annual costs netted from incremental annual benefits) and discounted to obtain the present value of the costs and benefits. Finally, the decision to invest in SCS or TPS depends on the magnitude of the measures of project worth (NPV, IRR, B/C).

We used 8 years' project life because the investment would be productive during this period without a major replacement or additional investment. Costs and benefits were estimated on the basis of 1994 prices. The currency unit was the drachma (Drs) (1 U.S. dollar = 250 drachmas; Bank of Greece, 1994).

Production and gross returns for SCS and TPS were compared. From the output of each experimental period, the statistical mean of the total and marketable production of strawberries was estimated for 2 years (the differences among cultivars were not taken into consideration).

Marketable strawberry production included the yield obtained for categories: Extra (E > 20 g/fruit), A quality (A = 14–20 g/fruit), and B quality (B = 9–14 g/fruit); total production included the above plus C quality (C = 5–9 g/fruit) and D quality (D < 5 g/fruit) (Clamont et al., 1986; Paraskevopoulou-Paroussi et al., 1995). Although the above categories do not represent pure quality standards, they clearly reflect Greek consumers' preferences, since the larger the fruit, the more willingly the consumer pays a higher price. Farmers can mainly sell strawberries weighing >9 g/fruit, but smaller fruits (C and D) are sold in exceptional cases at lower prices. Production and gross returns were estimated for the total area of the greenhouse and they are based on 0.1 ha. Gross returns were computed using actual price data surveying the local market once a week.

Results and Discussion

Production. Total production of SCS exceeded the total production of TPS by an average of 240% (Table 1), and surpassed the marketable production by an average of 195%. Furthermore, SCS gross returns exceeded those of TPS by 438% for total production and by 367% for marketable production. However, overall effectiveness of TPS cannot be assessed only by production and gross returns comparison.

Financial comparison of SCS and TPS. Judging by year-to-year expenses for SCS and TPS, fixed costs for SCS were extremely high the first year when the system was installed, making the net cash flow negative (Table 2). Variable costs were also extremely high for SCS; however, after the first year, higher production counterbalanced the high cost and yielded a positive net cash flow. High variable costs from year to year were mainly due to fuel costs and, partly, due to high harvest expenses.

The NPVs were determined by considering the monetary flows of the productive system of SCS against TPS based on a 0.1-ha greenhouse (Table 2). The specific expression of the NPV is Eq. [1]. We applied Eq. [1] under the assumption that the rate of inflation affects

Table 2. Costs and revenues (Drs millions)[z] of the soilless culture system (SCS) for strawberry production and for the traditional production system (TPS), 0.1 ha (Thessaloniki, Greece, 1994).

	Cost						Gross revenues		Net cash flow	
	Fixed[y]		Variable[x]		Total					
Year	TPS	SCS	TPS	SCS	TPS	SCS	TPS	SCS	TPS	SCS
1	304	4.702	469	3.469	774	8.171	1.140	4.183	366	−3.988
2	0	0	441	3.395	441	3.395	1.140	4.183	699	788
3	0	0	462	3.469	463	3.469	1.140	4.183	677	714
4	48	470	448	3.395	496	3.865	1.140	4.183	644	318
5	70	70	463	3.469	533	3.539	1.140	4.183	607	644
6	0	0	441	3.395	441	3.395	1.140	4.183	699	788
7	48	470	470	3.469	518	3.939	1.140	4.183	622	244
8	0	0	441	3.395	441	3.395	1.140	5.803	699	2.408

[z]All prices are expressed as 1994 Drs. (1 U.S. dollar = 250 Drs).
[y]Fixed costs are the greenhouse structure, the erection-glazing, the polyethylene covering, the irrigation system, the recorder equipment, and the SCS structure.
[x]Variable costs are the plants, the perlite, the fuel, the nutrition solution, the water, the plastic bags, the plastic mulch (white and black), the soil disinfection, the sprays, the insurance, the labor, the harvest cost, and the maintenance.

Table 3. Financial analysis of the soilless culture system (SCS) in comparison with the traditional production system (TPS), 0.1 ha. (Thessaloniki, Greece, 1994).

Financial components	Fruit production[z] Total	Marketable
Net present value (NPV) (Drs[y])	–83,200	–3,378,000
Net present value (adjusted for inflation) (Drs)	–73,500	–3,384,000
Internal rate of return (IRR) (%)	14.28	---
Benefit cost ratio (B/C)	0.99	0.89
Payback period (PP) (years)	5.73	8
Discounted payback period (DPP) (years)	8	8

[z]Values represent net present value (NPV), internal rate of return (IRR), benefit/cost ratio (B/C), payback period (PP), and discounted payback period (DPP), respectively, when SCS rather than TPS was used.
[y]Drachmas.

costs and revenues similarly; consequently, costs and benefits remain constant in relation to each other. The discount rate was set at 15%, since it was the common rate charged in agricultural investment projects in 1994 by Greek banks. This figure seems also plausible considering that inflation in 1994 was 11%.

When total production under SCS was compared with that of TPS, NPV was negative (Table 3), as it was for marketable production. Thus, implementation of SCS instead of TPS was not profitable under current cultivation conditions and costs, despite its effectiveness in increasing production and gross returns.

The IRR for total production was slightly lower than the assumed discount rate (15%) (Table 3). The B/C ratios for total and for marketable production were <1 (Table 3), indicating that adoption of SCS as an alternative to TPS does not contribute to additional profits.

The PP was determined by adding up the expected returns in successive years until the total value equaled the original outlay. By using linear interpolation, a relatively large PP of nearly 6 years (total production) was found (Table 3). For marketable production, PP was ≈40% longer. The DPP is a more conservative measure of relative liquidity; it indicated that the initial investment would be recovered similarly for total and for marketable production (Table 3).

Evaluation of SCS applying NPV model adjusted for inflation. The production systems were evaluated in an inflationary environment by applying Eq. [2], which gives NPV adjusted for inflation. We assumed that the inflation decreased by 0.5% per year during the life period of the investment (8 years), taking into consideration the European Union's (EU) economy convergence plan, which requires a gradual annual inflation reduction.

When SCS was compared to TPS, NPV adjusted for inflation was always negative. For total production, adjusted NPV was 88% of unadjusted NPV (Table 3). This result happens because of the nonconstant cash flows during the project's life which, when adjusted for inflation, can almost recover the large negative cash flows of the first year, a period when the inflation rate was higher. For marketable production, adjusted NPV was almost the same for unadjusted NPV (0.16% higher) (Table 3).

Sensitivity analysis. To perform a more accurate evaluation of SCS, the effect of a change in certain variables on the discounted cash flow returns was examined. NPVs were estimated by assuming changes in the product price, yield, fuel price, and the discount rate. The ceteris paribus conditions for performing sensitivity analysis were assumed to be average for the experimental period. Thus, the product price was taken as 714 Drs, the average yield as 7,212 kg/0.1 ha, and the fuel price and the discount rate as 92 Drs/L and 15%, respectively.

The product price is an important factor that affects NPV. A 10% increase in product price induced NPV to grow by 2462% (for total production) and by 40% (for marketable production). Thus, early production or well-planned timing of production can increase the benefits substantially, taking into consideration that earlier production is sold at a higher price. There was a positive linear relation between product price and NPV (Fig. 1), since gross returns equal yield × the product price.

Yield also was a significant factor that influenced NPV (Fig. 2). A 10% expansion in yield caused a 71% increase in NPV for marketable production and a 1847% increase for total production. Importantly, the yield change affects the magnitude of NPV the same way as

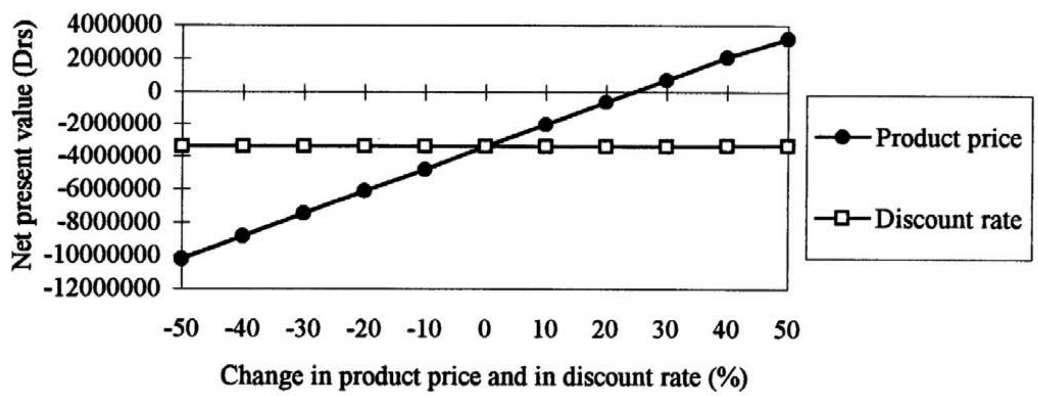

Fig. 1. The effect of a change in product price and in discount rate on net present value (NPV), 0.1 ha (Thessaloniki, Greece, 1994).

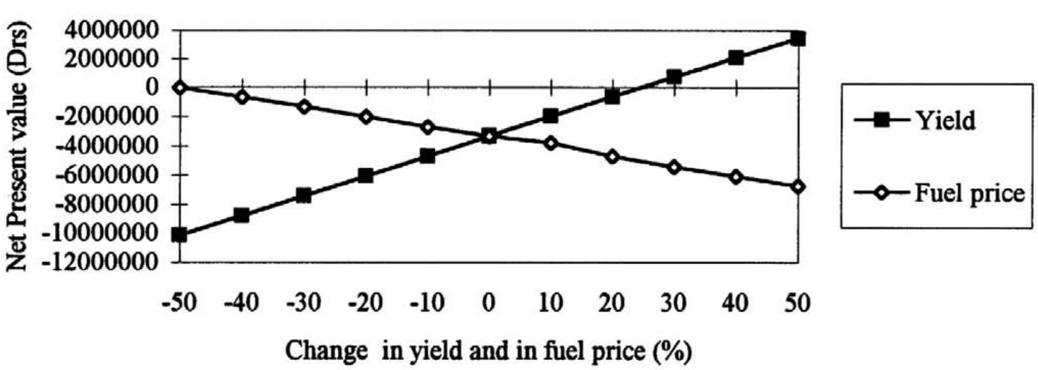

Fig. 2. The effect of a change in yield and in fuel price on net present value (NPV), 0.1 ha (Thessaloniki, Greece, 1994).

a price change, because yield also was linearly related to gross returns.

Cultivars producing higher yield and larger fruits also will yield a higher NPV. Thus, the financial analysis that considered cultivar differences in yield, the highest yielding cultivar, 'Selva', resulted in the highest NPV (–1,699,700 Drs), followed by 'Fern' (–3,183,800 Drs) and 'Brighton' (–7,020,900 Drs).

Fuel price had a great effect on farmers' income; a decrease of 10% increased NPV by about 80% for marketable production, and an increase of 10% caused a 20% drop in NPV (Fig. 2). Thus, a moderate decrease in fuel price would turn SCS into a profitable system. This finding is very important, not only because the fuel saving technique can make SCS profitable, but also because subsidizing the fuel price for agricultural use (a common practice in EU countries) can make SCS a beneficial technique.

Changes in the discount rate did not affect materially the magnitude of NPV, hence any increase in the discount rate can not change NPV more than 1% (Fig. 1).

Conclusions

The use of the vertical bag system of hydroponics culture for off-season strawberry production represents a technological innovation that could have promise for protected cultivation. However, financial analysis revealed that use of SCS in heated greenhouses, instead of TPS under plastic tunnels, did not provide sufficient benefits to farmers with present costs and returns. Sensitivity analysis indicated the importance of yield, product price, and fuel price in affecting benefits. Thus, the establishment of SCS cultivation could be supported mainly by either earlier production sold at higher prices, or by the adoption of more productive cultivars. The adoption of fuel saving technologies also would garner substantial benefits.

Our data demonstrates that farmers could not garner any additional income by implementing SCS in protected strawberry cultivation in northern Greece, and probably not in areas with a similar climate. The methodology we used can be applied in any other case where a new cultivation practice is compared to a traditional one.

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