EMPLOYING SOILLESS CULTURE SYSTEMS IN STRAWBERRY PRODUCTION

MARGARITA BENTES (*) - KONSTADINOS MATTAS (**)
GEORGIA PAROUSSI (***) - IRENE TZOURAMANI (****)

Abstract

Isolated soilless growing systems emerge today in intensive agricultural production and in particular for producing out of season strawberries. This study presents and evaluates two employed techniques of strawberry cultivation in heated greenhouse for out of season production. The vertical bag Soilless Culture System (SCS) and the Soil Mixture System (SMS) are used to estimate the expected net revenues from the adoption of these techniques, in the area of Northern Greece. Experimental data from the Agricultural Research Centre of Northern Greece were collected and analysed. Several approaches of investment appraisal such as Net Present Value, Internal Rate of Return, Benefit/Cost ratio, Payback Period, and Discounted Payback Period had been employed. The importance of the Soilless Culture System (SCS) has been revealed in terms of increasing production and gross returns. When compared with Soil Mixture System (SMS), it has also been proved to be an important contributor to farmers' income.

Résumé

Les systèmes de culture sans sol isolés s'imposent de plus en plus dans la production agricole intensive et notamment pour la production des fraises hors saison. Cette étude présente et évalue deux techniques de la culture de la fraise sous serres rechauffées pour la production hors saison. Le Système de Culture Sans Sol (SCSS) en sac vertical et le Système de Mélange du Sol (SMS) sont utilisés pour estimer les revenus nets prévus grace à l'adoption de ces techniques dans la région septentrionale de la Grèce. On a récolté et analysé les données expérimentales du Centre de Recherche Agricole du Nord de la Grèce. Différentes approches d'évaluation ont été utilisées, telle que la Valeur Actuelle Nette, le Taux de Rentabilitè Interne, le rapport Avantages/Coûts, la Période d'amortissement et la Période d'amortissement actualisée. L'importance du Système de Culture Sans Sol (SCSS) s'est manifestée en termes d'accroissement de la production et des produits bruts et, vis-à-vis du Système de Mélange du Sol (SMS), il s'est avéré améliorer grandement le revenu de l'agriculteur.

Nowadays, greenhouse cultivation has changed radically. Goals of earliness, productivity increase and product quality improvement resulted in farmers adopting new skills for enhancement of crop productivity and more-effective management of resources. The greatest change has been the move away from soil cultivation to isolated growing systems (Hall *et al.*, 1988). However, farmers produce off-season agricultural products and sell them in a very competitive world market, hence the lower the production cost, the larger the profit margins are (Salem *et al.*, 1993). So, the choice of the production system in order to obtain out-of-season production, constitutes a significant part to achieve higher levels of profitability. These aspects are quite relevant for horticultural commodities in general, and especially in the case of strawberry production.

This study presents and evaluates techniques of strawberry cultivation in heated greenhouses using Soilless Culture Systems, particularly the vertical bag system of hydroponics culture, for out-of-season production in the area of Northern Greece. Therefore, production and gross returns for Soilless Culture System (SCS) and Soil Mixture System (-SMS) under plastic tunnels were evaluated and compared. The magnitude of the benefits provided by such technologies were estimated and compared using various appraisal criteria such as: Net Present Value (NPV), Internal Rate of Return (IRR), Benefit/Cost ratio, Payback Period and Discounted Payback Period.

Strawberry production

Strawberry is one of the most extensively grown crops with the aid of plastic (greenhouses, tunnels, row covers or soil mulches). Strawberries can be cultivated in greenhouse, under plastic tunnels, or in open fields.

Once production is affected by the climate conditions, soil and water management, and cultivar and cultivation technique, it is possible to have a different apportioning of production during the harvest period. This can be an advantage to satisfy the demand all year round, especially if the peak of production occurs out-of-season, which means during the winter time for Mediterranean area.

Kourouklis (1986) mentioned that between 1982-84 a decrease in open field production and a corresponding increase in greenhouse production, from 25% to 57% was recorded, the main reason for this change being the possibility offered by protected cultivation to achieve out-of-season production, to increase output and to avoid the negative effects of weather conditions.

Strawberry greenhouse production in Greece is relatively small compared to other horticultural products. Both climate and distance from the markets constitute economic constraints on location of strawberry production. Greenhouses in northern areas located near big cities, require little transportation for strawberries produced under protection but require large amounts of heat to offset the cold climate.

In general, the cost of strawberries produced in greenhouses is burdened a little.

Approximately thirteen years after Greece's accession to the European Union the strawberry production varied between 16,278 and 7,000 tons which corresponds to a decrease of 57% (FAO, 1992). Greek strawberry production has decreased sharply after 1981 from 16,278 to 4,451 tons in 1986, which corresponds to a decrease of thirty four percent in 1982, thirteen percent in 1985 and forty eight percent in 1986. After that, it has increased up to 8,592 tons in 1990. This increase was not constant: twenty seven percent between 1986 and 1987; eleven percent in the next two years and twenty two percent from 1989 to 1990. Another decrease of 13% occurred in 1991. For 1992, the total marketable production was forecasted at about 7,000 tons (**figure 1**), (FAO, 1992). The biggest part of production is concentrated in the Northern Greece areas (Pieria, Florina and Pella).

(*) Graduate student of Maich Chania
(**) Professor of Agricultural Economics at the Aristotle University of Thessaloniki.
(***) Researcher of Agricultural Research Centre of Northern Greece.
(****)Associate Researcher of Agricultural Economics and Social Research Institute, PhD student at the Aristotle University of Thessaloniki.

Strawberry cultural methods

In Greece, strawberry is traditionally grown outdoors or under plastic tunnels without providing any heat, as a result, the production period is short and the market is oversupplied in very short time span (May). Therefore, farmers in order to improve the conditions of strawberry production and obtain higher income have been tried various techniques.

According to Morgan (1985), cultural methods have changed considerably as a result of the introduction of cold-stored waiting-bed (CSWB) plants; the development of micro propagation systems for rapid multiplication of healthy plants; the breeding of short-day, overbearing day-neutral cultivars; the utilisation of cheap protection e.g. floating mulches and low and walk-in plastic tunnels; finally, the introduction of new growing techniques based on peat, rockwool and NFT.

Sarooshi (1987) and Decazos (1991) reported five soilless culture techniques for growing strawberries: Nutrient Film Technique (NFT), Aeroponic Systems, Cut pipe/channel gravel system, The Ein-Ged system, Vertical sac cultivation or the hanging bag system.

The last one, the vertical cultivation is considered very much interesting. The rosette habit of growth of strawberry and the small size of the plant, enable growers to grow strawberries in vertical surfaces and in various levels. In this system the production becomes less dependent on the available greenhouse surface area (Chalkia, 1990).

The vertical system of hydroponic culture is an improvement of the traditional protected strawberry cultivation (tunnels) with the use of advanced construction techniques. It is obvious that this system makes better energy utilisation and more efficient use of the greenhouse volume, resulting in higher yield per unit area, by planting the strawberry plants in a certain way along the columns, one above the other, and increasing plant density area to 24,000 - 28,000 plants per 1000m^2. This means almost four or five times more plants than the traditional way of cultivation in soil (Tropea, 1980). The plants are arranged in pre-determined positions on vertical columns filled with a suitable inert substrate of various materials (Chalkia, 1990). Giorlando (1978) refers to some expected advantages, such as:

a) Better use of the greenhouse area, since there are used 200,000 - 250,000 plants/ha, approximately five times more than in traditional cultivation.

b) Possibility to produce in regions where the soil is not fertile or has undesirable properties.

c) Saving of labour. The concentration of the plants into a smaller area increases the efficiency of labour.

d) Saving of cultural means (fertilisers, pesticides, plastic films), lower cost of irrigation and heating.

e) Better control of parasites and pests, since the plants are not exposed to soil burn diseases and air circulation in various levels of the plantation decreases the possibility of Botrytis infection.

f) The plants are exposed to uniform environmental conditions (substrate, ambient air).

g) The product is clean, free from soil particles, residues of fertilisers and other impurities.

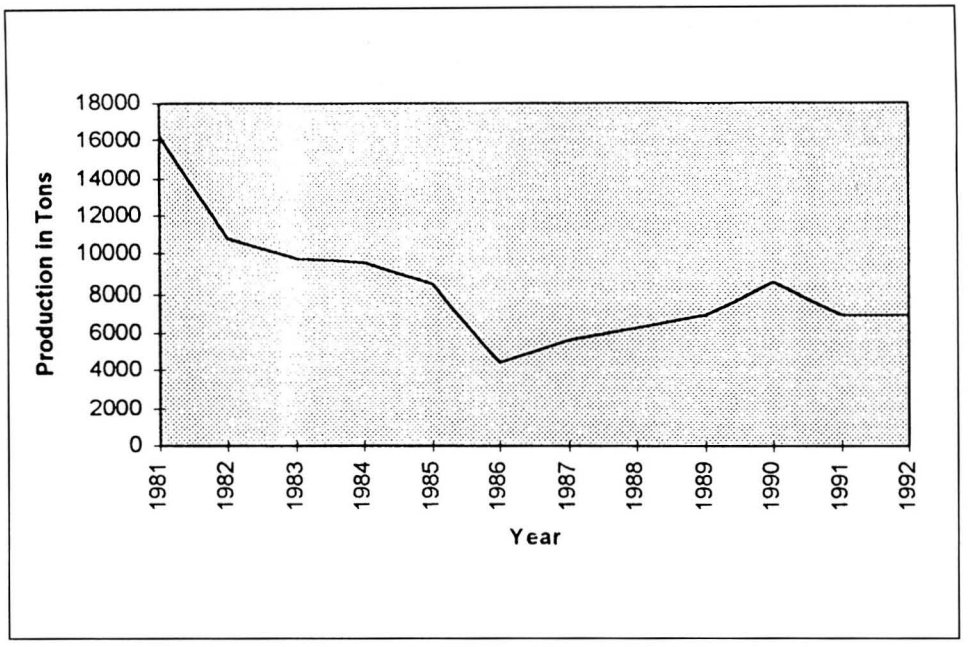

Figure 1 - Greek strawberry production (1981-1992). Source: FAO, 1992.

Soilless Culture System (SCS)

Strawberry plants were planted in vertical plastic bags made of white polyethylene tubes, 2m of height and 16cm of diameter filled with agricultural perlite, which were installed at intervals of 0.80 x 1.0 m, about 1000 bags/stremma (1000 m^2). On each bag twenty four plants were planted and the bag density in the greenhouse was about 1 bag/m^2 which leads to a total of 24 000 plants/stremma. Metallic beams were used to support the vertical bags (Paraskevopoulou - Paroussi *et al.*, 1993).

Nutrient solution was released with two drippers, of 4 litters/hour/dripper capacity, through feeding pipes into the upper and middle part of the bags. Holes were made in the bottom of the bags to allow the solution to be drained into a tank in order to be tested and if necessary corrected with supplementary fertiliser. The storage tanks, with 1 ton capacity, were placed inside the greenhouse (Paraskevopoulou - Paroussi *et al.*, 1993).

Soil Mixture System (SMS)

Strawberry plants were planted in black plastic pots filled with 5 litters/pot of soil mixture. The plastic pots were distributed in double rows at a distance on and within the rows of 40 cm and between the double rows of 50 cm, so that the density in the greenhouse would be about 5000 plants/stremma (5 plants/m^2). The soil mixture was enriched with an initial nutrition according to the estimated needs of the crop, although 2 or 3 times per week the same nutrient solution used in the SCS was applied (Paraskevopoulou - Paroussi *et al.*, 1993).

Financial analysis

Methodology

In the agricultural sector, financial evaluation of capital investment projects can be made using one or more of the discounted measures: Net Present Value (-

NPV), Internal Rate of Return (IRR), Benefit/Cost ratio (B/C), Payback Period (PP) and Discounted Payback Period (-DPP) (Pagoulatos, 1992).
The most commonly employed evaluation technique to determine project's feasibility is the Net Present Value (-NPV). The application of this method involves annual operating expenditures (-costs) to be netted against annual inflows (benefits) in order to obtain the project's net cash flows (Longmore, 1989). According to Brigham (1985) NPV is the value of the expected net cash flows of an investment, discounted to an appropriate percentage rate and subtracted from the initial cost outlay of the project. This can be written for our particular case as follows:

$$NPV = \sum_{t=1}^{8} \frac{CF_t}{(1+r)^t} \qquad (1)$$

Where:
CF_t = net cash flow in year t
r = the appropriate discount rate
t = project's expected life

Having set the discount rate, it follows that an investment project will be deemed acceptable if the sum of the discounted net benefits (benefits minus costs) is positive. This sum is sometimes called the Present Net Worth (NPW) or Net Present Value (NPV) of a project (Irvin, 1978). The corresponding investment decision rule is:

NPV > 0: accept the project
NPV < 0: reject the project

In this study, eight years' project life were used because during this period the investment would be productive without a major replacement or additional investment. Moreover, this time-period was used partly because more meaningful results can be obtained and partly because long-run price changes couldn't be predicted otherwise. Costs and benefits were estimated on the basis of 1994 prices. The currency unit was the drachma (Drs.) (1 Dollar = 250 Drachmas) (Bank of Greece, 1994).
The NPVs were determined by considering the monetary flows of the two productive systems SCS against SMS referred to a base area of 0.1 ha greenhouse. The real discount rate used in the analysis was set at 15%. The application of equation (1) was under the assumption that the rate of inflation affects both costs and revenues in the same way; thus the result was to leave costs and benefits constant.

Materials

Data were obtained from experiments conducted at the Agricultural Research Centre of Northern Greece in the region of Thessaloniki. Also, variable production costs for greenhouse and open field cultivation were estimated using data provided by Paraskevopoulou - Paroussi (1994). Fixed production costs were obtained from Salem (1992) for the heating system and from Tzouramani *et al.* (1995) for greenhouse construction. Strawberries daily market prices were obtained from Sindos Wholesale Market (Thessaloniki). The experiments were carried out during 1992-93 and 1993-94. In the experimental period of 1992-93 the cultivars Brighton and Selva were used, while in the experimental period of 1993-94, the cultivars Fern and Selva were used.
A round arch-type greenhouse with vertical side walls (single span) was used (Tzouramani *et. al.*, 1995), covered with polyethylene, having a double roof, automatic sidewall openings and with a south-north orientation. It was heated with warm air originated from a central diesel boiler (Diesel-fired Furnace System [DFS]), and an automatic thermostatic system was adjusted to control high temperatures. The greenhouse area was equal to 200m^2. The ground was covered with white plastic mulch to ensure light reflection for the plants at the bottom part of the vertical bags and to control the weeds.
In the experimental period of 1992-93, the plants were planted on August, 20. They were transplanted to vertical plastic bags filled with perlite and to plastic pots filled with soil mixture. In the next experimental period, 1993-94, the transplantation period occurred on September, 2. Plants and perlite were renewed every crop season.

Production and gross returns

A comparison of production and gross returns was made between Soilless Culture System (SCS) and Soil Mixture System (SMS). From the output of each experimental period, the statistical mean of the total and marketable production of strawberries was estimated for two years (The differences among cultivars were not taken into account).
As marketable strawberries production is set the yield obtained by the categories (E+A+B) and as total production the yield from categories (E+A+B+C+D) (Paraskevopoulou - Paroussi *et al.*, 1993). This distinction was taken into consideration since very often market conditions allow farmers to sell fruits (-for fresh consumption) that are not included in categories E, A, and B. As average market prices for the referred E, A and B categories, 400 Drs/Kg, 350 Drs/kg and 300 Drs/Kg are considered, respectively. Production and gross returns were estimated for the total area of the greenhouse and they are referred at a base of 0.1 ha (1 stremma).
Table 1 illustrates obtained production and annual gross returns for the two systems under comparison. The total production of the SCS exceeded that of the SMS by an average of 324% and in terms of marketable production it also exceeded SMS by an average of 335%. The gross returns obtained from SCS were greater by 354% (for total production) and by 364% (for marketable production) than in the SMS.
Cultivation of strawberries in heated greenhouses promotes earliness, a fact that allows earlier marketing when prices are likely to be higher. According to Paraskevopoulou - Paroussi *et al.* (1993) production obtained from November until March is considered as very early, while that from November until April is considered as early production. The adoption of SCS in a heated greenhouse had, as a result, 60% of its total production during the period from November until March, and a corresponding gross return of 75%. In contrast, SMS achieved 46% of its total production with corresponding gross returns of 64%, in the same period. Considering the early production period (November-April), both systems achieved more than 70% of their total production, confirming the effect of heating on promoting earliness.
Prices of strawberries were analysed, during the study period, to determine seasonal patterns. Generally, they were higher in December/January and declined in April. A comparison with the distribution of the gross returns showed that the peak of the gross returns is biased from the peak of the market prices of about one month, both for SCS and SMS. **Table 2** shows how the early production allows to exploit higher market prices.
Generally, production considered as very early allows to exploit higher market prices, whereas marketable production obtained by SCS achieved the highest average market price (938 Drs/Kg). In terms of total production, both systems (SCS and SMS) exploited similar average market prices for the three pro-

duction periods.

Financial analysis

Evaluation of the SCS compared with SMS

The evaluation of the SCS was based on the application of the model (Equation 1) regarding NPV and for the other appraisal criteria, IRR, B/C ratio, PP and DPP. Several parameters were determined before calculation. Analysis concern the case of no distinction among cultivars. The application of the discount cash flow approach is illustrated in **tables 3** and **4**.

The decision rule for NPV criteria is to accept all investments with a positive NPV. The use of the SCS, over an 8-year period, produced a NPV of 9,093.069 Drs for total production, indicating a significant increase in earnings of greenhouse farmers (**table 3**). When marketable production was taken into consideration, the SCS gave a NPV of 6,812,952 Drs, indicating in the same way a significant increase in farmers' income (**table 4**). Since all the terms of the discounted cash flows are positive and the NPV is also positive at each value of the interest rate, the determination of the IRR is impossible because NPV does not cross the discount rate axis; whence, IRR was not taken into consideration.

The evaluation of a project by the B/C ratio method requires acceptance of the project if the ratio is greater than one. The obtained ratio values were 2.32 for total production and 2.01 for marketable production, confirming the NPV method and indicating the profitability of the SCS when it substitutes the SMS.

In both cases (total and marketable production) the original outlay would be recovered in a short payback period (less than one year). This ensures the profitability of the investment. When DPP method is applied it indicated that for total production the initial investment would be recovered during the first year as with PP criteria, whereas for marketable production it shows that it will happen a little bit later : 1.08 years after. Thus, both results ensure the profitability of the investment.

Conclusions

The application of the vertical bag system of hydroponics culture for out-of-season strawberry production represents a technological innovation which

Table 1 ***Average annual total and marketable strawberry production (kg) and Average annual gross returns (Drs) in different production systems (area = 0.1 ha).***

		SCS	SMS	Index*
Annual Average Production	Total Production	7211.16	2228.05	324
	Marketable Prod.	5860.20	1750.83	335
Gross Returns	Total Production	4991280	1409270	354
	Marketable Prod.	4182888	1147475	364

* as 100 is considered the corresponding in SMS.

Table 2 ***Average market price (Drs) in each production system.***

	Total Production		Marketable Production	
	SCS	SMS	SCS	SMS
Very early	874	880	938	880
Early	776	729	799	433
Total	692	633	714	655

Table 3 ***Financial analysis of the SCS in comparison with the SMS, 0.1 ha (Drs) for total production*.***

Year	Cash Outflows	Cash Inflows	Cash Flow	Discount Factor (15%)	Discounted Cash Outflows	Discounted Cash Inflows
1	1685547	3582010	1896463	0.870	1466426	3116349
2	1508547	3582010	2073463	0.756	1140462	2708000
3	1518547	3582010	2063463	0.657	997685.4	2353381
4	1508547	3582010	2073463	0.572	862888.9	2048910
5	1518547	3582010	2063463	0.497	754717.9	1780259
6	1508547	3582010	2073463	0.432	651692.3	1547428
7	1518547	3582010	2063463	0.356	540602.7	1275196
8	1508547	3582010	2073463	0.327	493294.9	1171317
Total	12275376	28656080	16380704	4.467	6907769	16000839

* (1994 Exchange rate 1$ = 250drs).

Table 4 ***Financial analysis of the SCS in comparison with the SMS, 0.1 ha (Drs) for total production.***

Year	Cash Outflows	Cash Inflows	Cash Flow	Discount Factor (15%)	Discounted Cash Outflows	Discounted Cash Inflows
1	1649386	3035413	1386027	0.870	1434966	2640809
2	1472386	3035413	1563027	0.756	1113124	2294772
3	1482386	3035413	1553027	0.657	973927.6	1994266
4	1472386	3035413	1563027	0.572	842204.8	1736256
5	1482386	3035413	1553027	0.497	736745.8	1508600
6	1472386	3035413	1563027	0.432	636070.8	1311298
7	1482386	3035413	1553027	0.356	527729.4	1080607
8	1472386	3035413	1563027	0.327	481470.2	992580.1
Total	11986088	24283304	12297216	4.467	6746238	13559190

has a promising, beneficial use in protected cultivation. Its effectiveness was assessed by accounting all the monetary returns or expenses resulting by the installation and operation of the Soilless Culture System (SCS) in a strawberry heated greenhouse, in comparison with simple heated greenhouse cultivation in Soil Mixture (SMS) in Northern Greece. Results revealed that, the implementation of the SCS in heated greenhouse increased production and gross returns dramatically, in particular through the promotion of early production due to heating. From the agronomic point of view, the vertical bag cultivation of strawberries presents some limitations in increasing the plant density. The desired development in the number of plants along the column which could raise profitability of the system is limited, due to problems related mainly with light intensity, particularly to the plants at the bottom of the column. Perhaps, an increase between rows which could lead to a reduction in installation costs, or the application of white mulch accomplished by the introduction of the Passive Solar System (PSS) could be used to improve both temperature and light reflection at the bottom of the columns. More investigation to explain the relationship between substrate and cultivar sh0ould be undertaken in the future. Alternative substrates to perlite, some of them low costing, or re-used, should be considered.

Financial analysis which was based on different methods allowing the assess of investment profitability – such as NPV, IRR, B/C ratio, PP and DPP – demonstrated that the adoption of the SCS significantly increases the earnings of greenhouse strawberry producers instead of the SMS. ●

References

Anagnostou, K., 1993, *Out-of-season strawberry production under vertical soilless culture in a glasshouse: Effects of substrate and cultivar on earliness, productivity and fruit quality*, M.Sc. Thesis., Mediterranean Agronomic Institute of Chania, Greece.

Brigham, E.F., 1985, *Financial Management. Theory and Practice*, 3rd Edition, Holt-Sauneders, International Editions, Chapter 3: 46-64; Chapter 11: 370-412.

Chalkia, C., 1990, Vertical cultivation of strawberries, Unpublished essay, Mediterranean Agronomic Institute of Chania, Greece.

Decazos, D.E., 1991, *Small Fruits*, ISBN, Athens, 500 pp (in Greek). *Cited by* Anagnostou, 1993, above.

FAO, 1992, *FAO Yearbook - Production*, FAO Statistics Series 46 (112), Rome.

Giorlando, A., 1978, La fragola in coltura verticale fertirrigata. FRUTTICOLTURA III-IV, 23-30 (in Italian). *Cited by* Chalkia, 1990, above.

Hall, D.A.; G.M. Hitchon, and R.A.K. Szmidt, 1988, Perlite culture: a new development in hydroponics. Proceedings of the International congress on Soilless Culture, International Society for Soilless Culture, 177-183, 12 ref.

Irvin, G., 1978, *Modern Cost - Benefit Methods*, The Macmillan Press LTD, London and Basingstone, Chapter 1: 1-22; Chapter 2: 23-41; Chapter 3: 42-60.

Kourouklis, S.D., 1986, Strawberries: Production, international market, perspectives, Organismos Proothiseos Exagogon, Athena: 39 pp. (in Greek)

Longmore, D.R., 1989, The persistence of the payback method: a time-adjusted decision rule perspective, THE ENGINEERING ECONOMIST, 34 (3), 185-194.

Morgan, J.V., 1985, Maximising yield and quality in strawberry crop, CEC Workshop, September.

Pagoulatos, A., 1992, *Investment Project Analysis*, TMI, Lexington.

Paraskevopoulou-Paroussi, G., 1994, Unpublished experimental data, Agricultural Research Centre of Northern Greece.

Paraskevopoulou-Paroussi, G., E. Paroussis and M. Grafiadellis 1993, Precocity, plant productivity and fruit quality of strawberry plants grown in soil and soilless culture, ACTA HORTICULTURAE, (in press).

Salem, A., 1992, *Economic evaluation of a passive solar greenhouse heating system*, M.Sc. Thesis., Mediterranean Agronomic Institute of Chania, Greece.

Salem, A., K. Mattas and M. Grafiadellis, 1993, Assessing low-cost input use in of-season tomato production, ACTA HORTICULTURAE 340, 117-124.

Sarooshi, R., 1987, Hydroponic growing strawberries. In: Hydroponics Workshop. Salamander Bay, 16-18th March, 1987, NSW. 93pp. *Cited by* Anagnostou, 1993, above.

Tropea, M., 1980, The control of strawberry plant nutrition in sack culture. ISOSC Proceedings: 477-484. *Cited by* Anagnostou, 1993, above.

Tzouramani, I., K. Mattas and M. Grafiadellis, 1995, Directing Farmer's Greenhouse Construction Decisions, MEDIT 6(2), 44-48.