OPTIMIZING FERTIGATION OF EGGPLANT PRODUCTION IN HYDROPONIC COCO-PEAT SUBSTRATE

Edgard Tabet[a], Reda Awali [a], Dalida Darazi[b], Chadi Hosri[c] and Salwa Tohmé Tawk[d]

[a]Faculty of Agronomy, Department of Plant Production, Lebanese University, Dekwaneh, Lebanon.

[b]Faculty of Agronomy, Department of Plant Protection, Lebanese University, Dekwaneh, Lebanon.

[c]Faculty of Agronomy, Department of Animal Production, Lebanese University, Dekwaneh, Lebanon.

[d]Faculty of Agronomy, Department of Economy, Lebanese University, Dekwaneh, Lebanon.

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ABSTRACT

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This research aims at optimizing eggplant cultivation by comparing hydroponic fertigation recipes in coco-peat substrate with traditional soil cultivation. The first two groups of 36 plants each are fertilized according to the recipes recommended by two companies (A and B), treatments 1 and 2 respectively. The third is fertilized according to the conventional method in the soil adopted by farmers (group C). Company A applies standard fertilizer application protocol throughout the life of the plant with a stable pH and electro conductivity of 6 and 2.8 mS / cm respectively. Company B applies an upward fertilizer scheme during the plant's production cycle with a stable pH of 5.6, but an electro conductivity that varies from 2.1 mS / cm at the vegetative phase to 2.5 mS / cm from the appearance of the 1st fruit. Despite its high investment, the two hydroponic treatments T1 and T2 showed greater plant size (127 cm and 129 cm respectively at the 12th week), more fruits (15 fruits per plant each week, compared to 8 fruits per plant in the soil), and higher yield (average mass per plant reached a maximum value at the 11th week of 1.192 g for T1 and 1,189 g for T2 compared to 499 g for the soil). The difference in revenues shows a negligible financial advantage in favor of Company B. Adopting fertilization recipe of Company A or B is not a limiting factor at the financial level hence either one of the two formulations is adequate.

Keywords: eggplant, hydroponic, soilless culture, coco-peat, fertigation.

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INTRODUCTION

The term "soilless culture" generally refers to any method of growing plants without the use of soil as a rooting medium (Savvas, 2003; Savvas et al., 2013). Because plants do not feed on the soil, but minerals that are in the soil, hydroponics is created to make these minerals available directly from the water (Hydroponov, 2011). The cultivation hydroponic allows to control and balance the nutrition of plants. The literature review has shown that hydroponic cultivation is widespread throughout the world and that this technique has been well adopted in developed countries for a long time and has shown its cultural, environmental and socio-economic advantages compared to the conventional cultivation (Sharma et al., 2019). It is mainly practiced in the Northern European countries (the Netherlands and Belgium) and in France (Sharma et al., 2019), and is currently being spread in the Mediterranean countries.

Coconut fiber is ideal for the production of hydroponic eggplant. This substrate combines the water retention of vermiculite with the air retention of perlite, but it is a fully organic substrate and made entirely from shredded coconut shells. It provides the plant with an ideal rooting medium and also provides protection against root and fungal diseases. Unlike peat moss, which is rapidly depleted and piled up, coir is entirely renewable (Roberto, 2003).

The coco peat substrate is essentially a mixture of two materials. The first is coconut powder derived from the mesocarp tissues, or the outer hard part of the coconut (*Cocos nucifera* L.) characterized by a density of 0.04 to 0.08 g.cm-3, and a total porosity and area of about 90% and 11% respectively (Evans et al., 1996). The other material is coconut fibers with different characteristics (a total porosity of 98% and a porosity of air of about 70%) (Lemaire et al., 1998). The powder retains the water very well while the fibers provide very good aeration. Therefore, by putting different proportions of fiber and powder into the substrate, optimal characteristics can be achieved (Wever & Van Leeuwen, 1995).

Finally, this substrate, in pure form, is rich in Na and Cl, which can harm the plant; for this, the substrate must be washed and leached by adding calcium (Ca) and magnesium (Mg) to facilitate the removal of sodium. On the other hand, the content of phosphorus (P) and potassium (K) is relatively high which must be taken into account in fertilization programs (Noguera et al., 2000).

The use of local, natural resources and renewable raw materials and waste is becoming an international trend (Gruda, 2012; Barretta et al., 2016). According to Khachatryan et al. (2014), the consumer is willing to pay more for products perceived as being 'environmentally friendly'.

The irrigation system used is a micro-irrigation system (drip irrigation) being the most efficient in the use of water (Sharma et al., 2019). Indeed, the containers are irrigated and fertilized by a transmitter and a 'spaghetti' tube. The choice of space between emitters, their rates and their numbers depends on the design of the system (Fenneman et al., 2012).

The amount of water at each irrigation is controlled by the water retention potential of the medium; it is irrigated until the medium is saturated. It was reported that the quality of irrigation water may be limited by the concentration of certain phytotoxic ions, substances and microorganisms (Tognoni et al., 1998). Besides, it is necessary to make a chemical analysis of the water to be used in the nutrient solution, to know the concentration of each ion and subtract a quantity of these ions from the fertilization formulation (Gómez-Merino & Trejo-Téllez, 2012).

Eggplant (*Solanum melongena* L.) is an important greenhouse crop in most Mediterranean countries. World eggplant production is estimated at 52,309,119 tons in 2017. Lebanon ranks 34th in the world in eggplant production, with a yield of 43,606 tons and a harvested area of 1,636 ha (Food and Agriculture Organisation [FAO], 2017). The price of a ton of eggplant is estimated at around $ 1250 (FAO, 2014).

Eggplant can be grown successfully in most commercial soilless culture systems, including cultivation in substrates and nutrient solution (Savvas et al., 2013).

Eggplant is a plant requiring high intakes of macronutrients; reported amounts of nitrogen from 6 to 7 kg, phosphate from 1 to 1.5 kg, potash from 6 to 7.5 kg and calcium such as magnesium from about 0.5 kg / ha / ton harvested (Chaux & Foury, 1994).

In order to successfully grow hydroponic eggplant, the pH must be maintained between 5.8 and 6.5 in the substrate. To reduce the pH, acids are added to the nutrient solution of which the most used are nitric, sulfuric and phosphoric acid (Gómez-Merino & Trejo-Téllez, 2012).

There are several formulations of the mineral composition nutrient solutions, and these solutions are used in tomato and eggplant. The initial composition of the irrigation water is always considered. The irrigation water may contain some macronutrients (Ca2+, Mg2+, SO4 2-), micronutrients (Mn2+, Zn2+, Cu2+, B and Cl-) and other non-nutrient ions (HCO3-, Na+) at appreciably high concentrations (Sonneveld & Voogt, 2009). These nutrients have to be taken into consideration when the amounts of fertilizers needed to prepare a nutrient solution (NS) are calculated. Hence, the fertilizer masses needed to prepare a NS of a specific composition should be individually computed for each grower (Savvas & Gruda, 2018). Moreover, the nutrient needs of a plant species may change at different developmental stages (Sonneveld, 2002; Savvas et al., 2013).

Cultivating under greenhouses and in closed hydroponic systems can substantially reduce the pollution of water resources by nitrates and phosphates stemming from fertigation effluents, and contribute in minimizing the use of water and fertilizers (Savvas, 2001). In Lebanon, the contamination of the water sources by pesticides is one of the most critical environmental problems (Kouzayha et al., 2013). Youssef et al. (2015) and Chbib et al. (2016) analyzed the presence of pesticides in groundwater samples in South Lebanon and North Lebanon respectively and noted the need of pesticides' monitoring programs. No research projects dealing with fertigation on eggplants in Lebanon have been achieved, which makes this work original with regional interest. The objective of this study is to compare the eggplant cultivation under greenhouses in the soil with soilless cultivation in coco peat substrate closed system under two different fertilization recipes to reduce the use of inputs and improve quality of produce.

MATERIAL AND METHODS

Site description

The experiment was carried out between April 25th and July 25th 2016 in the Adloun region, a village in the suburbs of Saida 75 km south of Beirut (Lebanon) and 60 m above sea level. The study was conducted in an 84 m2 specially designed greenhouse for the experiment, containing 72 hydroponic eggplant pots and 36 eggplant plants in the open field. Irrigation intervals, cultural practices, and disease and pest control were similar to all treatments in our open system soilless culture study. The appearance of the first flower buds took place around May 25th, 2016 and the first harvest took place on June 10th, 2016.

Climate

According to the meteo station of LARI (Lebanese Agricultural Research Institute) in Tyre, the temperature during the production phases varied between 12 and 33 ° C although the relative humidity varied between 30 and 90%.

System installation

The greenhouse where the experiment took place is a greenhouse of 6 m width and 14 m length, with a height of 3.5 m. Its sides are protected by insect-proof nets that improve ventilation and reduce humidity and temperature. This lateral opening promotes the circulation of fresh air entering from the sides and expels warm air through the roof.

Soil preparation

The greenhouse was divided into two compartments. In the first part the pots were installed on a black mulch to prevent the development of weeds and to better secure the pots. While in the second part the eggplant plants were planted directly in the soil according to conventional practices.

Irrigation system

A water tank (r) of 6000 liters capacity powered by an artesian well has been installed. Also four other tanks of capacity 200 liters each were installed, of which two (r1 and r2) contain the nutritive solutions of the first treatment (T1), and the two others (r3 and r4) contain the nutritive solutions of the second treatment (T2). The nutrient solutions of each of the two treatments (T1) and (T2) contain immiscible substances. The elevation of all the tanks was 9 m above the ground. The tanks r1, r2, r3 and r4 were connected to the tank r by a 20 mm diameter polyethylene pipe. At the meeting point R with r1 / r2 and the same R with r2 / r3, the nutrient solutions mix and feed the treatment pots T1 and T2.

Water analysis

The water used for irrigation and fed by an artesian well was analyzed in the laboratories of LARI Laboratories (Table 1). The results of the Electro conductivity (EC), Total Dissolved Solids (TDS), pH, Ca, Mg and K where used by the two companies to propose the composition of the fertigation recipes for an optimum production of eggplants (refer to tables 2 and 3).

Table 1. Results of the analysis of well water implementing the system.

Element	Value
Electroconductivity EC (µs/cm)	1240
Total Dissolved Solids TDS (mg/L)	793
Ph	7.01
Calcium Ca (mg/L)	136
Magnesium Mg (mg/L)	14.5
Potassium K (mg/L)	2.5
Sodium Na (mg/L)	90
Iron Fe (mg/L)	0.12
Hydrogen carbonate HCO3 (mg/L)	331
Chlorine Cl (mg/L)	92
Nitrate NO3 (mg/L)	121
Sulfuric acid SO4(mg/L)	37

Experimental design

The 108 plants grown in the experiment were divided into three groups of 36 plants each.

The first group T1 and the second group T2 consist of 36 plants each. The third conventional group (C) groups 36 plants grown in the soil. Both groups T1 and T2 were grown in substrate pots for hydroponic cultivation. The substrate used was Coco Peat. The pots used were black plastic pots with a capacity of 18 liters. They were covered with a white nylon to minimize the heating of the walls. The plants of the three groups were grown on the same date (25 April, 2016) with equal irrigation intervals. Each group received a different fertilization scheme (refer to section 2.7). Both groups T1 and T2 were supplied with water and fertilizers by ‘spaghetti’ tubes and capacity transmitters of 4 liters / hour each. Each plant was fed by a transmitter for 4 to 5 minutes during each irrigation (0.12 liter per irrigation) and 12 times a day (1.44 liters per day). While group C was supplied with water and fertilizers by the conventional method adopted by farmers which is drip irrigation (1.5 liters per day).

Since hydroponic cultivation requires frequent irrigations (reaching up to 12 times a day in early summer) irrigation was automated using a timer that opens and closes solenoid valves. Two plants from each line and two plants from each column were chosen for parameter measurement.

Choice of plants and planting

The plants selected in this experiment were non-grafted eggplant plants of the "Dream" variety. It is a semi-long variety that offers a product of average weight of 100 g, it was chosen for its high productivity potential and for its good quality fruit. The 108 plants selected for the experiment were 8 cm in average size and 5 weeks old.

Size and training of plant

Each plant was carried by two strands forming a letter V. These are attached by a plastic ring with the plant and then attached to a wire (plant hatch). The plant is driven by its two heads that appear above the first flower, and each head follows a string. During the crop cycle, leaves that did not have sufficient access to yellow light were cut with pruning shears and removed from the greenhouse.

Fertigation

The fertigation applied for the hydroponic plants was based on the fertilization recipes provided by the two companies A and B, while the plants grown in the soil were fertilized according to the recipe adopted by the farmers.

Company A applies the standard fertilizer administration protocol throughout the life of the plant with a stable pH and electroconductivity of 6 and 2.8 mS / cm respectively (Table 2).

Table 2. Fertigation Recipe from Company A.

Electroconductivity EC (mS/cm)	2.8	Phosphoric acid	171 ml
Ph	6	Manganese sulphate	3.38 g
Calcium nitrate	186 g	Zinc sulphate	2.88 g
Potassium nitrate	986 g	Copper sulphate	0.37 g
Ammonium sulphate	235 g	Borax	7.62 g
Fe-chelate	35 g	Sodium Molybdate	0.24 g
Magnesium Sulphate	827 g	Nitric acid	401 ml
Magnesium nitrate	235 g		

Company B applies a protocol for upward fertilizer administration during the plant's production cycle with a stable pH but an electro conductivity that ranges from 2.1 mS / cm at the vegetative phase to 2.5 mS / cm from the appearance of the first fruit (Table 3).

Table 3. Fertigation Recipe from Company B.

Vegetative phase (week 1 to 6)		**Reproductive phase (week 7 to 12)**	
Electroconductivity EC (mS/cm)	2.1	EC (mS/cm)	2.5
Ph	5.6	pH	5.6
Calcium nitrate	0	Calcium nitrate	0
Potassium nitrate	785 g	Potassium nitrate	1038 g
Ammonium sulphate	279 g	Ammonium sulphate	301 g
Fe-chelate	35 g	Fe-chelate	35 g
Magnesium Sulphate	0	Magnesium Sulphate	330 g
Magnesium nitrate	1234 g	Magnesium nitrate	585 g
Phosphoric acid	171 ml	Phosphoric acid	171 g
Manganese sulphate	3.38 g	Manganese sulphate	3.38 g
Zinc sulphate	2.88 g	Zinc sulphate	2.88 g
Copper sulphate	0.37 g	Copper sulphate	0.37 g
Borax	7.62 g	Borax	7.62 g
Sodium Molybdate	0.24 g	Sodium Molybdate	0.24 g
Nitric acid	400ml	Nitric acid	401 ml

The fertilization recipe from Company A was applied to the T1 group and the fertilization recipe from the Company B was applied to the T2 group.

Electro-conductivity and pH were measured daily using a conductivity meter and a pH meter to control nutrient solutions. These two devices were calibrated regularly, once a week.

Measured parameters

The parameters were measured weekly for six weeks: from week 7 after transplanting the 3 weeks old seedlings until week 12.

During the entire experiment, the stem length of each plant of the three treatments was measured using a measuring tape which was placed on the neck of the plant and directed to its apex. The number of fruits of each plant was manually counted from the beginning of the seventh week. The fruits of each plant from the three treatments were weighed using a precision scale from the seventh week until the twelfth week.

Economic analysis: Net Present Value Criterion

At the end of our experience, an assessment of the economic benefit of the three systems was done to determine the cost and profitability of each treatment based on the "Net Present Value" criterion (NPV).

NPV is defined as the difference between the present value of cash inflows and the present value of cash outflows; and it is used in capital budgeting to analyze the profitability of a projected investment or project. The rate of discount applied represents the cost of capital to the owners of the project and the period of discounting extends until the terminal year of the project.

A positive NPV indicates that the projected earnings generated by a project or an investment are greater than the anticipated costs; generally, an investment with a positive NPV will be a profitable one and one with a negative NPV will be considered as a loss.

The NPV formula is expressed as follows (Chibly, 1990):

$$NPV = -C0 + R1 - C1/(1+r)^1 + R2 - C2/(1+r)^2 + \ldots + Rn - Cn + Sn/(1+r)^n$$

Where:
C0: Immediate capital cost of the project
C1...Cn: Capital cost and operating cost incurred in each respective year
R1…Rn: Expected revenue stream of the project
r: Rate of discount used which is equivalent to the cost of capital of the owner
n: Life span of the project
Sn: Salvage value of the investment in year n

According to this formula, "NPV" varies directly with the benefits and/ or revenues stream and inversely with the cost stream of the project and the rate of discount applied. Thus assuming other variables to remain constant, the higher the revenues are the higher is NPV; the higher costs and rate of discount are the lower is the NPV.

Statistical analysis

The tables were made on the Excel 2016 program whereas the significant differences were processed by the SPSS Statistics version 16.0 software.

RESULTS AND DISCUSSION

Length of the plant

During the entire cycle of production, the results of the length of the stem are shown in table 4.

Table 4. Length of the eggplant plant during the production cycle.

Week	Mean ± standard deviation of plant length (cm)		
	Treatment		
	T1	T2	soil
1	8.2 ± 0.78[b]	9.1± 1.2[b]	5.5± 1.2[a]
2	11.4 ± 0.79[b]	11.8± .93[b]	6.5± 1.2[a]
3	21 ± 0.93[b]	21.3± 1.28[b]	10.4± 1.55[a]
4	35.6 ± 2.2[b]	37.1± 2.5[b]	15.5± 2.8[a]
5	53.3 ± 3.1[b]	55.2± 3.9[b]	31.2± 4.4[a]
6	69.3 ± 6.3[b]	70± 4.6[b]	44.9± 6.3[a]
7	92.3 ± 5.1[b]	95.2± 5.7[b]	63.9± 5.8[a]
8	110 ± 5.4[b]	111± 7.0[b]	93± 7.2[a]
9	118 ± 5.4[b]	119± 5.1[b]	97.8± 6.3[a]
10	123 ± 4.4[b]	125± 4.7[b]	101± 4.9[a]
11	126 ± 4.9[b]	127± 3.8[b]	106± 10.8[a]
12	127 ± 4.5[b]	129± 2.9[b]	110± 3.7[a]

** In lines, the numbers with similar exponent represent the absence of a significant difference at p> 0.05.*

The length of the plants during the production cycle shows an almost linear increase, for the T1 treatment the increase is low during the first two weeks (8.2 and 11.4 cm), it becomes more significant after the establishment of the root system and becomes 110 cm at the 8th week. Then it weakens with fruit production and ends with a length of 127 cm in the 12th week.

The T2 treatment shows results of the stem length very close to T1 with values of 9.1 and 11.8 cm for the 1st and 2nd week, it increases to reach 111 cm at the 8th week, and ends at 129 cm at the 12th week.

For plants grown in the soil, the length of the plant increases with a lower rate. In the first four weeks, it shows a small increase (5.5 to 15.5 cm) and then accelerates after root establishment which is slower in the soil, because of the more rigid physical structure, to become 93 cm in the 8th week. Then it weakens with fruit production and ends with a length of 110 cm in the 12th week.

On the other hand, between the T1 and T2 treatments, the length of the plant shows a non-significant superiority in favor of T2 having a lower electro-conductivity during the whole production cycle and especially the first 6 weeks (vegetative development), this is more or less in agreement with Texier (2013), who cited that a lower electro conductivity promotes vegetative growth of the plant. Hence, it is recommended that salinity effects should be taken into account in order to prevent over application of saline water and yield loss (Mahjoor et al., 2016).

Hydroponic treatments show significantly greater size throughout the crop cycle, in addition to uniformity as seen from lower standard deviations. This is in agreement with Texier (2013) who states that hydroponics ensures a healthy, rapid and homogeneous growth of the plant.

The results of the length of the plant during the 12 weeks of cultivation are insignificant between the treatments T1 and T2, but higher than that of the culture in full soil. This shows that the addition of fertilizer to increase the electro conductivity of T1 has no advantage in our experimental conditions vis-à-vis the length of the plant and that the cultivation hydroponic shows a vast superiority over to conventional culture.

Number of fruits

The number of fruits per plant in each treatment during the last six weeks of the crop is presented in table 5.

Table 5. Number of fruit over time: average per plant per week.

Week	Mean ± standard deviation of the number of fruits		
	Treatment		
	T1	T2	In soil
7	2.25 ± 1.1^{b}	2.6 ± 0.9^{b}	0.7 ± 0.46^{a}
8	3.1 ± 1.8^{b}	2.1 ± 1.1^{ab}	1.2 ± 1.1^{a}
9	$7.3 \pm 1.2a^{b}$	8.3 ± 1.7^{b}	5.1 ± 2.2^{a}
10	12 ± 4.6^{b}	11 ± 3^{b}	3.4 ± 1.4^{a}
11	16.8 ± 4^{b}	15.4 ± 5.1^{b}	5.9 ± 1.9^{a}
12	15.4 ± 2.1^{b}	15.3 ± 3.1^{b}	8.1 ± 1.3^{a}

** In lines, the numbers with similar exponent represent the absence of a significant difference at p> 0.05.*

The last six weeks of the experiment represent the productive phase of the plant. The average number of fruits per plant of the T1 Treatment increased in a perceptible way on the 7th week with a value of 2.25 fruits per plant to reach a maximum of 16.8 fruits production at the 11th week. Similarly, the average fruit count of the T2 treatment increased from 2.6 to the 7th week, reaching its maximum of 15.4 at the 11th week.

The average number of fruits per plant in the soil started with 0.7 fruits in the 7th week to reach a maximum of 8.1 at the 12th week.

The average number of fruits per plant of the three treatments increases weekly to reach 15 fruits per plant each week for hydroponic treatments, compared to 8 fruits per plant in the conventional soil cultivation. This aligns with Texier (2013) who cited that the yield of hydroponic plants is greater than that of the ground. Between the two treatments hydroponic and during the entire reproductive cycle, no significant difference is observed despite the difference in electro-conductivity of 2.8 for T1 and 2.5 for T2 and the slight differences in nutrient solution components**.**

Plant yield

The average fruit mass in grams per plant in each treatment during the last six weeks of the crop is presented in table 6.

Table 6. Average mass of fruit per plant over time.

Week	**Mean ± standard deviation of fruit mass per plant (in g)**		
	Treatment		
	T1	**T2**	**soil**
7	245 ± 148^{b}	307 ± 102^{b}	82 ± 65^{a}
8	186 ± 164^{a}	264 ± 102^{b}	143 ± 129^{a}
9	650 ± 121^{b}	682 ± 127^{b}	384 ± 144^{a}
10	1,190 ± 346^{c}	847 ± 223^{b}	360 ± 119^{a}
11	1,192 ± 320^{b}	1,189 ± 402^{b}	435 ± 150^{a}
12	1,072 ± 163^{b}	1,109 ± 213^{b}	499 ± 171^{a}

** In lines, the numbers with similar exponent represent the absence of a significant difference at p> 0.05.*

The average mass per plant for T1 treatment increased from 245g in the 7th week to reach its maximum value at the 11th week of 1.192 g. Similarly, for T2 the average mass per plant increased by 307 g to reach a maximum of 1,189 g in the 11th week.

In open-field cultivation plants produce at the beginning 82 g / plant and finish with 499 g at the 11th week.

For T1 and T2 treatments, it is noted that there is no significant difference in average mass per plant except during week 8 when T2 is greater than T1, and at week 10 when T1 is higher than T2. This difference between treatments T1 and T2 is sometimes in favor of T1, and sometimes in favor of T2, which does not present any advantage of one treatment over the other.

Between the hydroponic and the soil treatments, a remarkable difference occurs during the 6th weeks, in fact, for the last weeks, the yield of the plants grown in hydroponic is more than twice that of soil.

In addition, the results show that despite the difference between the nutrient solutions of the T1 and T2 treatments, no benefit arises by the addition of nutrients.

The advantage is the maintenance of an appropriate water and nutrients level within the substrate which prevents plant stress. However, better water nutrient- use efficiency is observed in the case of closed systems than in open ones (Putra and Yuliando, 2015).

Economic analysis

In this study, calculation is done in Lebanese Pounds or LBP (1 United States Dollar or USD = 1,500 LBP). The average loan interest rate in the Lebanese Markets is 12% (source, Lebanese Central Bank).

The calculation of the financial balance sheet is based on a plot with an area of 3000 square meters (sqm) and a 9-month production cycle which is a minimum surface area adapted to the financial capacities of small-scale farmers. The duration of the chosen production cycle is 9 months, the long season of the eggplant crop (FAO, 2013). The planting season starts mid-August and ends around mid-June. The harvesting starts at the end of the month of September. The land tenure is the cost of the rent estimated to be 3,000,000 LBP per year for the area considered. The opportunity cost for the farmer for the same area is estimated to be the cost of a part-time engineer for the soilless culture (12,600,000 LBP per year or 700 USD per month over 12 months) and less than a part-time job for the soil culture (5,400,000 LBP per year or 300 USD per month). The average yield for the soilless culture is estimated to be a minimum of 13 Tons per 1000 sqm hence 26 tons for the whole area considered compared to 7 Tons and 21 Tons respectively for the soil or conventional culture. The average price at farm level is 1000 LBP per kg.

The initial investment cost in year 1 and the common annual costs for the three treatments over nine years are presented in table 7. The costs cover some of the equipment.

Table 7. Common costs (C1 to C9) per year for the three systems in 1,000 LBP.

Description	C1	C2	C3	C4	C5	C6	C7	C8	C9
Galvanized iron	22,500	0	0	0	0	0	0	0	0
Polyethylene	5,700	0	0	5,700	0	0	5,700	0	0
Insect net	600	0	0	0	0	0	0	600	0
Land tenure/Rent	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Water cost	180	180	180	180	180	180	180	180	180
Fuel pump	400	0	0	0	0	0	400	0	0
Plastic twine	72	72	72	72	72	72	72	72	72
Seedlings	864	864	864	864	864	864	864	864	864

C1 to C9: Capital cost and operating cost incurred in each respective year.

The highest investment is the galvanized iron (22,500,000 LBP) in year 1, followed by the polyethylene plastic cover (5,700,000 LBP) replaced every 3 years, and the insect net (600,000 LBP) replaced every 7 years. The fuel pump at a cost of 400,000 LBP is replaced every 6 years. The land tenure (3,000,000 LBP per year) and the water cost (180,000 LBP) are common to all three systems despite the fact that water is used more efficiently in the soilless systems. The twines and the 3 weeks old seedlings (planted at 1,800 seedlings per 1000 sqm) have a cost of 72,000 LBP and 864,000 LBP respectively.

The annual costs that are different among the three cases are presented in table 8.

Table 8. Annual costs (C1 to C9) that differ among the three cases in 1,000 LBP.

Description	Cultivation system	Cost in 1,000 LBP								
		C1	C2	C3	C4	C5	C6	C7	C8	C9
Irrigation system	Soil	1,470					700			120
	Companies A et B	6,120					1,200			120
Soil/substrate preparation	Soil	180	180	180	180	180	180	180	180	180
	Companies A et B	14,700		4,320		4,320		4,320		6,720
Fuel for irrigation	Soil	150	150	150	150	150	150	150	150	150
	Companies A et B	900	900	900	900	900	900	900	900	900
Pesticides	Soil	896	896	896	896	896	896	896	896	896
	Companies A et B	560	560	560	560	560	560	560	560	560
Labor	Soil	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726
	Companies A et B	5,630	5,630	5,630	5,630	5,630	5,630	5,630	5,630	5,630
Fertilizers	Soil	900	900	900	900	900	900	900	900	900
	Company A	3,807	3,807	3,807	3,807	3,807	3,807	3,807	3,807	3,807
	Company B	3,438	3,438	3,438	3,438	3,438	3,438	3,438	3,438	3,438

Companies A and B have an automated and sophisticated irrigation with an initial cost of 6,120,000 LBP compared to 1,470,000 LBP for the soil cultivation. The maintenance is required on years 6 and 9. Soil preparation limited to ploughing in the soil cultivation has a fixed cost of 180,000 LBP per year; the hydroponic cultivation requires a good drainage system, a mulch cover, substrate and plastic pots at an initial cost of 14,700,000 LBP, renewal of coco-peat every other year at a cost 4,320,000 LBP, and mulch replacement on year 9 for 6,720,000 LBP.

Hydroponic cultivation requires continuous electrical power and frequent irrigation for 900,000LBP per year compared to only 1,500,000 LBP for soil cultivation.

Pesticide cost is lower in the hydroponic since the incidence of pests and diseases is lower than in the soil cultivation (FAO, 2013) hence the cost is 560,000 LBP and 896,000 LBP respectively. However, labor cost is higher due to the higher yield (5,630,000 LBP compared 3,726,000 LBP; similarly, the fertilizer cost is higher in hydroponic cultivation (3,807,000 LBP and 3,438,000 LBP for companies A and B respectively) compared to 900,000 LBP for the soil cultivation.

The Net Present Value over nine years for the three cases is presented in table 9 where the hydroponic systems show higher values.

Table 9. Net Present Value for the three cases, cost and revenue over 9 years in LBP.

Year	**Soil**		**Company A**		**Company B**	
	Cost	**Revenue**	**Cost**	**Revenue**	**Cost**	**Revenue**
1	46,038,000	21,000,000	77,633,000	39,000,000	77,264,000	39,000,000
2	15,368,000	21,000,000	27,613,000	39,000,000	27,244,000	39,000,000
3	15,368,000	21,000,000	31,933,000	39,000,000	31,564,000	39,000,000
4	21,068,000	21,000,000	33,313,000	39,000,000	32,944,000	39,000,000
5	15,368,000	21,000,000	31,933,000	39,000,000	31,564,000	39,000,000
6	16,068,000	21,000,000	28,813,000	39,000,000	28,444,000	39,000,000
7	21,468,000	21,000,000	38,033,000	39,000,000	37,664,000	39,000,000
8	15,968,000	21,000,000	28,213,000	39,000,000	27,844,000	39,000,000
9	15,488,000	21,000,000	34,453,000	39,000,000	34,084,000	39,000,000
Salvage value	9,247,500		9,650,000		9,650,000	
Total Net Present Value	1,590,183		2,172,958		4,375,017	

The salvage value at year 9 is 9,650,000 LBP and is calculated for the value of the galvanized iron (9,000,000 LBP), the fuel pump (450,000 LBP) and the plastic twine (200,000 LBP) at the end of the year. All three systems have a positive value at year 9 with 1,590,183 LBP for the soil system and 2,172,958 LBP and 4,375,017 LBP for the hydroponic systems. However, the initial cost covering is higher in the hydroponic systems than in soil system (49,620,000 LBP and 30,450,000 LBP respectively); this cost, calculated separately, covers the land preparation or substrate preparation, the irrigation system and the greenhouse structure and polyethylene cover and insect net.

The results comply with the FAO report mentioning the higher investment cost incurred by hydroponic cultivation (FAO, 2013) however fetching higher profit on the long term.

It is noteworthy mentioning that the difference between Companies A and B is the fertilization cost which is 3,807 LBP and 3,438 LBP is not showing significant differences in the NPV which does not imply any advantage of one fertilization scheme over the other. The NPV is positive indicating a feasible project if the market in ensured and the production is yielding acceptable quality and quantity. However, many risks should be taken into consideration and adequate management of the system should be maintained which requires knowledge and investment from the farmers' side. The Net Present Value is in favor of both hydroponic systems over nine years. Hence adopting either fertilization schemes is advantageous for the farmer.

CONCLUSION

This study shows the economic feasibility of investing in hydroponic systems which leads to higher yields and hence higher profit. Lebanese farmers remain producing this crop at a relatively high and hydroponic cultivation could be a solution to use inputs efficiently and optimize production. However, the lack of technical knowledge of hydroponic cultivation remains a limiting factor for Lebanese farmers. This study shows that hydroponic cultivation of eggplants is more profitable than soil cultivation.

The treatments show higher economic profit; moreover, hydroponic eggplants have larger size and more uniform fruit size. Lower pesticides amounts are used which leads to healthier produce and less groundwater contamination. The total average weight of fruits per plant is higher in the hydroponic treatments A and B compared to the traditional soil cultivation. Despite the differences in plant size during the production cycle between treatments A and B, the fertilization schemes did not affect the total yield significantly. There was no difference between the two treatments A and B despite the difference in EC. Eggplant production shows to be optimized in hydroponic systems where the NPV at year 9 is 2,172,958 LBP and 4,375,017 LBP for T1 and T2 respectively. Further studies should investigate the effect of different irrigation frequencies on the efficiency of the system. Moreover, closed irrigation systems should be implemented to reduce the environmental impact of the waste water resulting from the open systems.

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