Water and Energy Use Efficiency of Greenhouse and Net house Under Desert Conditions of UAE: Agronomic and Economic Analysis

Abdelaziz Hirich and Redouane Choukr-Allah

Abstract The GCC (Gulf Cooperation Council) countries are considered one of the most water scarce region in the world, and facing over the coming years the most severe intensification of water scarcity in history. Protected agriculture area in the GCC countries is close to 13,000 ha and most of it are using Pad-fan cooling system which lead to high energy and water consumption. This research aims to assess the water and energy use efficiency between a high technology greenhouse equipped by pad-fan and sun screen system and a low technology net house equipped by a mist system. Three crops were cultivated, cherry tomato and sweet pepper under greenhouse and cucumber under net house. Greenhouse presented the highest water consumption used for cooling process. In fact, cooling consumes 2.6 and 3.5 times more water than the required irrigation water for sweet pepper and cherry tomato respectively. However, the fogging system in the net house was consuming less water, about 75% of consumed irrigation water used for cucumber. Data related to energy use were tremendously high where greenhouse consumed 32 times the energy used under net house. This study showed also that cooling cost in the total production cost is much higher and heavier under greenhouse resulting in high production cost and loss of competitiveness of the local product in the market where imported products seems to be more competitive than local produced products. Therefore, there is a need to improve energy and water use efficiency in the protected agriculture in GCC region and to reduce the water and energy footprint under protected agriculture in GCC region.

Keywords Yield · Cucumber · Cherry tomato · GCC region · Net house

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1 Introduction

Middle East countries are most water-scarce countries in the world, such as Saudi Arabia and Jordan, have per capita annual water resources less than 200 m^3. Overall, it is also expected that by 2025, due to population increase, the regional average water availability is projected to be just over 500 m^3 per person per year (Abdel-Dayem and McDonnell 2012). The overall objective of protected cultivation is to modify the natural environment by practices or structures to achieve optimal productivity of crops by enhancing yield (Wittwer and Castilla 1995). The GCC (Gulf Cooperation Council) countries are considered one of the most water scarce region in the world, and facing over the coming years the most severe intensification of water scarcity in history. Agriculture is the sector using by far the majority of available fresh water resources (>85%) of whish 92% is used for dates and forages production (Kotilaine 2010). Agriculture is the prime target for water conservation efforts, as it plays an important socio-cultural role (heritage) and within food security considerations. So, improving water management, performances and productivity in major agricultural systems is major issue within the strategy of most gulf countries. The Arabian Peninsula is also high food-importing, with abundant solar energy conditions is highly conducive to the use of renewable-energy (solar) (Alnaser and Alnaser 2011; El Katiri and Husain 2014). Protected horticulture can offer problem-solving approaches to challenges involving water and food supplies. Cultivation on substrates under protected conditions is one of the spearheads in this process (Wittwer and Castilla 1995).

Greenhouse production is considered as the most water conservative solution in the agriculture sector. In fact, protected crop production is now a growing reality throughout the world with an estimated about 4 Millions ha of greenhouses spread over all the continents (Choukr-Allah 2015). The degree of sophistication and technology depends on local climatic conditions and the socio-economic environment. The greenhouse production development in northern Europe stimulated the expansion of protected agriculture in other areas, including the Mediterranean, North America, Oceania, Asia and Africa, with various rates and degrees of success. It has been shown that a mere transposition of north European solutions to other parts of the world is not a valid process. Each environment requires further research, development, extension, training and new norms of application to meet local requirements.

The protected agriculture in the GCC countries is close to 13,000 ha and due to hot climate conditions the greenhouses are cooled which lead to high energy and water consumption (Al-Nasser and Bhat 1998). Greenhouse energy consumption is the largest component of the system's environmental impact, and this is true in particular during the hot season (May to September). For example the energy consumption in the greenhouse cooling in the mediterranean region is about 100,000 kWh/ha/year which leads to high energy cost (Kittas et al. 2012). This number should be bigger under GCC conditions where temperatures during the summer region are much higher than Mediterranean regions. Goals for reductions in energy consumption and a larger contribution from sustainable energy sources are of great importance for the Greenhouses growers.

In UAE, the number of greenhouses increased over the period 2005–2011 by 48% and 14,777 had been installed by 2011. This was accompanied by a 78% increase in the area so that greenhouses covered 493 ha in 2011. There were some regional differences, however, Abu Dhabi registering an increase in number while all other regions showing a reduction. The total crop production was 2.1 million tons in 2010 and 74% of this was from forages and field crops. Fruit trees contributed 19% while vegetables accounted for only 7%. The situation of protected agriculture changed significantly in 2011 when total production fell to 1.2 million tons and this may be due to salinity and water scarcity problems which call for better use of saline water and fresh water saving (NBS 2013). UAE is very dependent to foreign markets for its needs in fruits and vegetable, it imports 62 and 47% of vegetables and fruits needs respectively which indicates that there is a great potential to increase the horticultural production in UAE as well as the GCC region (Woertz et al. 2008).

The aims of this study is to compare between two cropping system, high-tech greenhouse cultivated with high cash crop cherry tomato and low tech net house cultivated with low cash crop cucumber. The comparison consists of yield, water and energy use and economic benefice.

2 Materials and Methods

2.1 Structure Description

The greenhouse and net house area is 560 m^2 each with two spans, each span has a width of 8 m, length of 35 m and height of 5 m (Fig. 1). The net house is equipped with a mist system consisting of nozzles with an hourly discharge of 32 l/h. In order to reduce the temperature and evaporation a shade net was installed above the mist system. The used net is an insect proof net with stitch dimensions equal to 1 × 0.5 mm. while the greenhouse is cooled through fan-pad system and equipped by automatic sun screen system. Both greenhouse and net house contain close drainage system where drainage water is recycled.

2.2 Climate Control

Climate under greenhouse and net house is controlled by computer where the temperature and humidity are monitored through Synopta software. Both greenhouse and net house are equipped by temperature and humidity sensors. The start conditions of the mist and fan-pad system set in the Hortimax system are presented in Table 1.

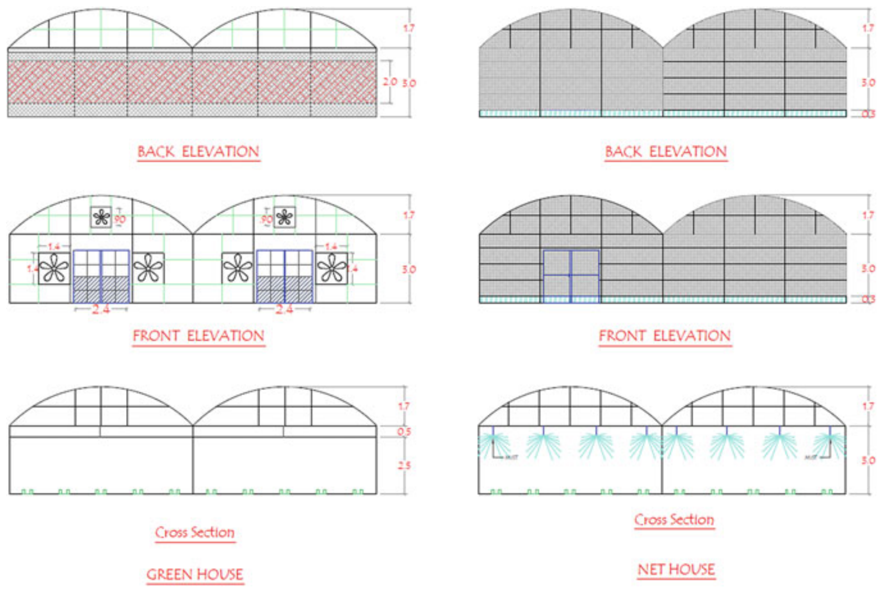

Fig. 1 Greenhouse and net house technical specifications

Table 1 Start conditions of cooling system in net house and greenhouse

Net house	Greenhouse
• Temperature set point for fogging: 29 °C • Relative humidity set point: 75% • Min air temperature for fogging: 15 °C • Min fogging duration: 20 s • Max fogging duration: 30 s • Min pause between 2 fogging cycles: 300 s • Start fogging at 10:00 a.m • Stop fogging at 17:00 p.m	• Cooling temperature set point: 26 for cherry tomato and 27 °C for sweet pepper • Relative humidity set point: 75% • Min temperature for top fan: 30 °C

2.3 *Fogging Operation*

Figure 2 shows the outside and inside net house temperature variation during the day. It is obvious that during the fogging period (10:00–17:00) the mist system with the shade net reduced temperature by about 6 °C. The shade net without mist system reduced temperature by only 3 °C. Under hot climate it is the high temperatures which cause more damage to cucumber especially when temperature exceeds 40 °C which leads to plant wilting and water loss. An appropriate irrigation management accompanied with fogging system can reduce significantly the heat damage on cucumber plants and thus avoid yield losses.

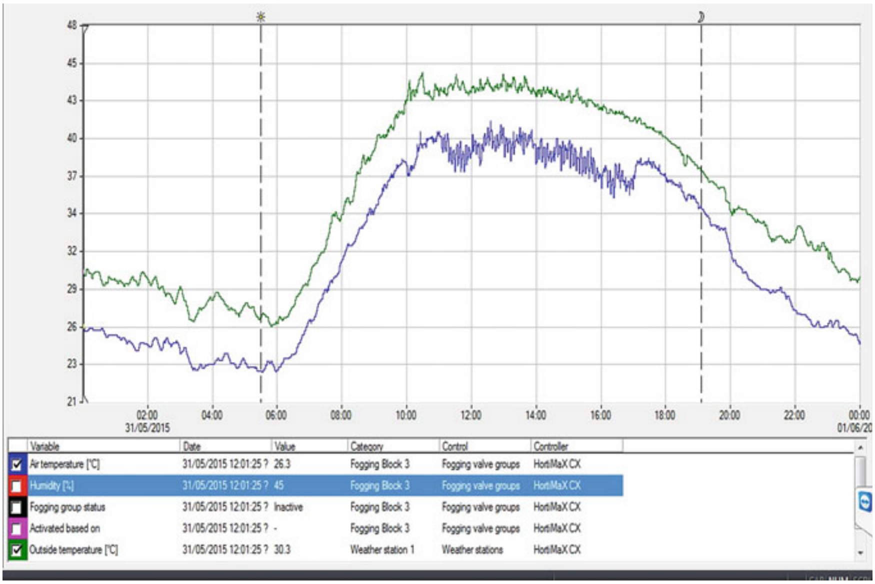

Fig. 2 Net house and outside temperature variation during the day

2.4 Growing Medium and Technical Practices

The whole system was controlled by computer through the Hortimax system. Irrigation and fertigation as well as climate control under greenhouse and net house were monitored automatically via Synopta software. Experimental design consisted of a completely randomized block design with 4 replications. Red dunes sand mixed with peat moss (2/3 sand + 1/3 peat) has been used as substrate in a polystyrene pot of 6 L. In the bottom of pots a layer of 3 cm has been filled with gravel to facilitate drainage. For plant fertilization the modified hoagland solution has been supplied for plants (Hoagland and Arnon 1950; Cooper 1988; Hochmuth and Hochmuth 2001). Drainage water was recycled and treated through a UV system (VITALITE) before reuse. Irrigation scheduling was carried out automatically based on accumulated radiations. Agronomic practices for both cucumber under net house and cherry tomato under greenhouse were carried out according to commercial farming practices.

3 Results

3.1 Water and Energy Use

Greenhouse presented the highest water consumption used for cooling process (Fig. 3). In fact, cooling consumes 2.6 and 3.5 times more water than the required irrigation water for sweet pepper and cherry tomato respectively. Deference of cooling water use for cherry tomato and sweet pepper is explained by the 1 °C difference of cooling setpoint. However the fogging system in the net house was consuming less water, about 75% of consumed irrigation water used for cucumber. Data related to energy were tremendously high where greenhouse consumed 32 times the energy used for fogging system in the net house. Therefore, there is a need to improve energy and water use efficiency in the protected agriculture in GCC region.

For a cropping period of 8 months for cherry tomato, 5 months for sweet pepper and 4 months for cucumber the projected water and energy use per hectare for cooling is raising more questions about the sustainability of cooled greenhouse in the GCC region, the most region affected by water scarcity in the world. However net house system seems to be more sustainable and could contribute significantly in water and energy saving. Further research is needed to explore more options for cooling using alternative water resources as saline and treated wastewater and to upgrade the existing greenhouse to be more efficient in terms of water and energy use.

3.2 Water and Energy Productivity

Figure 4 shows the obtained crop irrigation water productivity (CIWP) under both greenhouse and net house. Data indicate that 1 m^3 of irrigation water produced about 16 kg of cucumber (Zeco Variety), 10 kg of cherry tomato (Sarah variety) and 12 kg of sweet pepper (Red Mountain variety). This difference in terms of

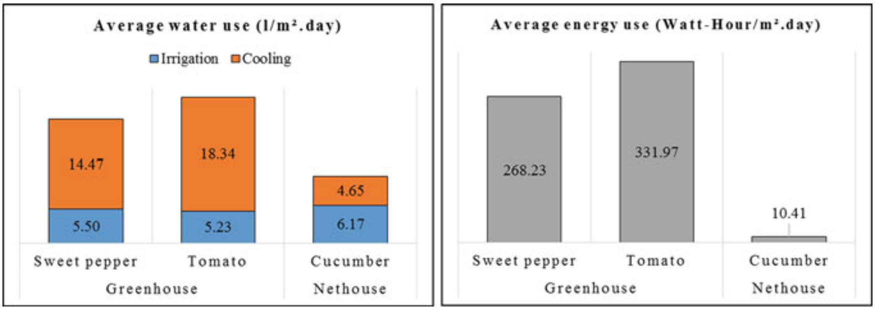

Fig. 3 Energy and water use under greenhouse and net house

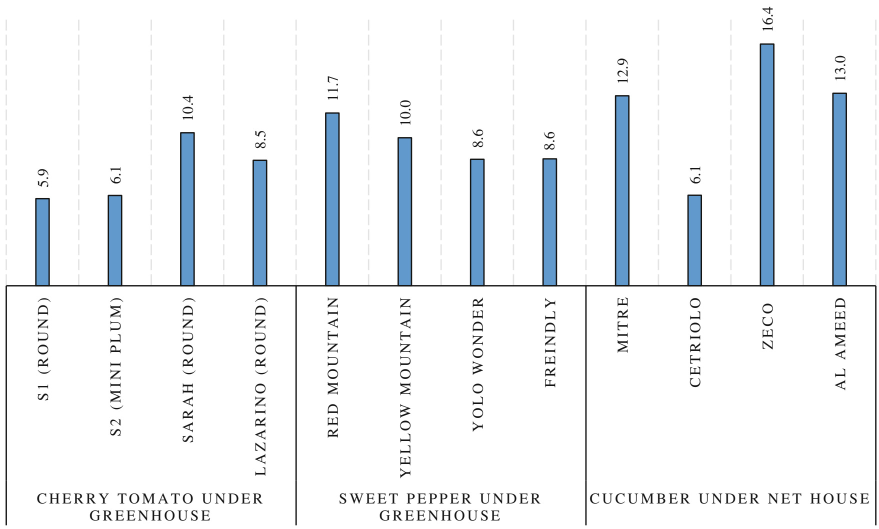

Fig. 4 Irrigation crop water productivity (kg/m^3) under greenhouse and net house conditions

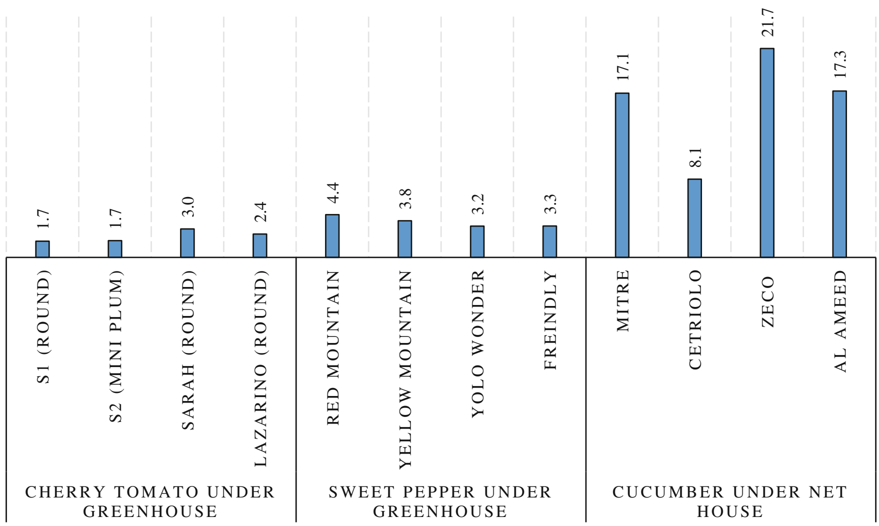

Fig. 5 Cooling crop water productivity (kg/m^3) under both greenhouse and net house

CIWP is explained by difference in plant species and cropping period (3 months for cucumber and 5 months for both cherry tomato and sweet pepper).

Crop cooling water productivity (CCWP) under net house and greenhouse is presented in Fig. 5. Data shows that the difference between net house and greenhouse was obvious in terms of CCWP where 1 m^3 of cooling water produced more

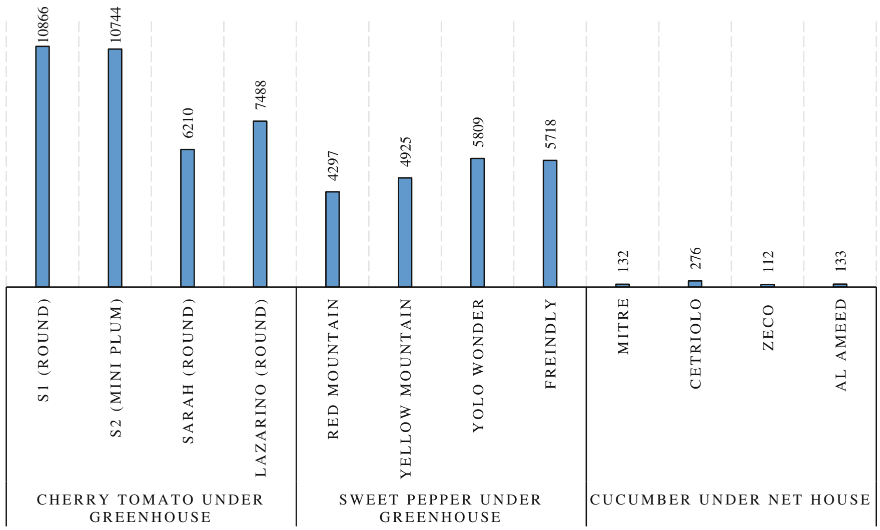

Fig. 6 Energy use efficiency under greenhouse and net house conditions

than 21 kg of cucumber (Zeco variety) and only 3 and 4 kg of cherry tomato (Sarah variety) and Sweet pepper (Red Mountain variety) respectively. Obtained result indicates clearly that net house is more efficient and more water saving compared to greenhouse.

Figure 6 shows the energy productivity under greenhouse and net house for 4 varieties of cucumber and cherry tomato. To produce 1 kg of cucumber (Zeco variety) we needed about 112 W-h, however to produce 1 kg of cherry tomato (Sarah variety) and sweet pepper (Red Mountain variety) we needed 6210 and 4297 W-h. These results indicates that energy component in the total production cost is much higher and heavier under greenhouse resulting in high production cost and loss of competitiveness of the local product in the market where imported products seems to be more competitive than local produced products.

4 Costs and Benefice Analysis

4.1 Investment

Table 2 presents the detailed costs of greenhouse (high technology) and net house (low technology). The data show that greenhouse cost per 1 m^2 is 1.5 times compared to net house and this difference is mainly due to greenhouse expensive components as the structure coverage. However the other components related to pumping and drainage recycling are both required for both structures. The table presents also the effective area can be served by greenhouse and net house

Table 2 Investments costs for greenhouse and net house

	Actual cost for 280 m^2	Effective served area (m^2)	Cost for 1 m^2
Greenhouse components			
Span (35 × 8) covered by 6 mm tick 2 layers PC sheet equipped with pad and fans cooling system	47,500	280	169.6
Drip irrigation system	4875	280	17.4
Drainage water system	28,000	10,000	2.8
Dosing unit	47,075	10,000	4.7
Technical room	43,200	50,000	0.9
Ground cover by 5 cm thick white gravel	6375	280	22.8
Total greenhouse investment cost	177,025	–	218
Net house components			
Span net house (35 × 8)	14,000	280	50.0
50 mesh white insect proof net	2000	280	7.14
Mist system	10,920	280	39.0
Drip irrigation system	4875	280	17.4
Drainage water system	28,000	10,000	2.8
Dosing unit	47,075	10,000	4.7
Technical room	43,200	50,000	0.9
Ground cover by 5 cm thick white gravel	6375	280	22.8
Total net house investment cost	156,445	–	145

components. This parameter is important when costs are projected at farm level because investment cost at experimental level per surface unit are very high compared to investment costs at farm level.

4.2 Investment Depreciation

Depreciation will be calculated by dividing the initial investment on total structure life period. All depreciation will be reported by month to be able to calculate investment depreciation equivalent for each growing period (3 months for cucumber and 5 months for cherry tomato and sweet pepper). Since the calculation will concern only the first research year, no discounted value will be updated. Table 3 shows the depreciation for all structures as well as the depreciation for each growing period. The net house structure depreciation is less than greenhouse structure and furthermore is the half when producing cucumber under net house compared to cherry tomato under greenhouse.

Table 3 Investment life period and depreciation

Components	Actual cost for 280 m^2	Life period (year)	Cost AED (m^2)	Depreciation AED/month	Depreciation AED/cropping period	
					Cherry tomato and sweet pepper	Cucumber
Greenhouse components						
Span (35 × 8) covered by 6 mm tick 2 layers PC sheet equipped with pad and fans cooling system	47,500	15	169.6	0.942	4.711	–
Drip irrigation system	4875	5	17.4	0.290	1.450	–
Drainage water system	28,000	15	2.8	0.016	0.078	–
Dosing unit	47,075	15	4.7	0.026	0.131	–
Technical room	43,200	15	0.9	0.005	0.025	–
Ground cover by 5 cm thick white gravel	6375	15	22.8	0.127	0.633	–
Total greenhouse investment cost	177,025	–	218	1.406	7.028	–
Net house components						
Span net house (35 × 8)	14,000	15	50	0.278	–	0.833
50 mesh white Insect proof net	2000	5	7.14	0.119	–	0.357
Mist system	10,920	10	39	0.325	–	0.975
Drip irrigation system	4875	5	17.4	0.290	–	0.870
Drainage water system	28,000	15	2.8	0.016	–	0.047
Dosing unit	47,075	15	4.7	0.026	–	0.078
Technical room	43,200	15	0.9	0.005	–	0.015
Ground cover by 5 cm thick white gravel	6375	15	22.8	0.127	–	0.380
Total net house investment cost	156,445	–	145	1.185	–	3.555

4.3 Running Costs

4.3.1 Labors

In general labor requirements vary according to the cropping system and crop species and technological level. In most of cases cherry tomato requires more labors compared to cucumber and sweet pepper and this due to its technical practices which should be carried out at daily basis.

The estimated time for the technical practices of cherry tomato, cucumber and sweet pepper is presented in Table 4. Presented data indicate that cucumber and sweet pepper require 3 permanent labors/ha while cherry tomato requires 6 labors/ha.

4.3.2 Fertilizers

For all crops we have adopted a Hoagland fertigation solution in its modified formula by Cooper (1988) and adjusted according to Hochmuth and Hochmuth (2001). The adopted fertigation solutions is presented in Table 5.

The used fertilizers quantity as expressed in g/m^2 is presented in Table 6.

The fertilizers price as well as the fertigation cost per each crops is presented in Table 7.

4.3.3 Pots and Substrates

Our calculation were based on results obtained under substrate containing 2/3 sand and 1/3 peat. Table 8 presents the substrates requirement as well as related costs.

Pot cost is related to pot market price, however one pot can be used for 3 years, it means 9 cropping periods of cucumber and 6 cropping periods of cherry tomato and sweet pepper. So the final cost will be divided either on 6 or 9. So the total cost related to substrate and pots is equal to 1.92 for cucumber and 2.19 for cherry tomato and sweet pepper.

4.3.4 Pesticides, Seeds and Other Costs

Table 9 presents the pesticides used quantity and equivalent costs for all tested crops. Presented results indicate that cherry tomato has consumed nearly 40% of used quantity and cucumber and sweet pepper have consumed about 25 and 35% respectively of the total used quantity of pesticides.

Table 10 presents the seeds price and costs and other costs related to the tested crops. Cherry tomato presents the highest costs in terms of seeds and other costs (rope, seedling trays, accessories, etc.).

4.3.5 Energy Costs

Energy costs concern the energy used for cooling, irrigation pumping and fresh water production. In our case fresh water is produced by Reverse Osmosis machine as most of groundwater in UAE is saline so many farmers have installed R.O machine for fresh water production. Farmers in UAE are paying 0.03 AED/kWh as energy price which is subsidized by the government. However the actual cost of

Table 4 Labors requirement for 1 ha per crop and cropping practice

Technical practice	Cucumber			Cherry tomato			Sweet pepper		
	Required labor	Nb of hours per labor	Working days/ha	Required labor	Nb of hours per labor	Working days/ha	Required labor	Nb of hours per labor	Working days/ha
Sowing and transplanting	2	8	2	2	8	2	2	8	2
Plant training	4	175	88	10	125	156	4	160	80
Plant pruning	2	116	29	8	210	210	5	80	50
Leaf removal	–	–	–	9	125	141	3	180	68
Harvesting	5	180	113	9	150	169	7	195	171
Plant inclination	–	–	–	8	60	60	–	–	–
Phytosanitary treatment	1	20	3	2	80	20	1	20	3
Total working days per cropping period			234			758			371
Total labors (ha_			3.11			6.06			2.96
Cost/day			112			112			112
Total cost (m^2)			2.52			8.4			4.2

Table 5 Fertigation solution, elements and fertilizers concentration

Fertilization unit	mg/l	Fertilizers (in mg/l)	mg/l
N	100	MAP	188
P_2O_5	115	Potassium nitrate	391
K_2O	180	Magnesium sulphate	415
CaO	210	Calcium nitrate	808
MgO	66	Fe	20
S	50	Cu	1
Fe	1	Mn	4
Cu	0.1	Zn	1
Zn	0.1	B	2
Mn	0.5	Mo	1
B	0.3		
Mo	0.1		

Table 6 Fertilizers consumption (g/m^2)

Fertilizers (g/growing period m^2)	Cucumber	Cherry tomato	Sweet pepper
Mono-ammonium phosphate	53.84	70.54	74.18
Potassium nitrate	112.25	147.05	154.64
Magnesium sulphate	119.05	155.95	164.00
Calcium nitrate	231.69	303.52	319.19
Iron chelate 6%	1.43	1.88	1.98
Copper	0.19	0.25	0.26
Manganese	1.10	1.45	1.52
Zinc	0.19	0.25	0.26
Boron	0.57	0.75	0.79
Molybdenum	0.36	0.47	0.49
Phosphoric acid	3.57	3.92	4.29

energy in UAE is much higher (0.25 AED/kWh) (Afshari and Friedrich 2016) and in order to encourage farmers government subsidized the energy used in agriculture. Table 11 shows the water and energy use as well as energy related costs. Obtained results indicates that to produce 1 m^3 of desalinated water we need 2.6 kWh of energy. It was shown also that cherry tomato was the highest consumer in terms of energy and especially the cooling part and this was due to cooling temperature which was equal to 26 °C less than the cooling temperature under sweet pepper greenhouse (27 °C). This result indicates that reducing cooling temperature increased the energy and related cost with about 24%.

Table 7 Fertilizers price and costs per each crop

Fertilizers	Package	Unit price	AED/kg or L	Cost AED/m^2		
				Cucumber	Cherry tomato	Sweet Pepper
Mono-ammonium phosphate (25 kg/bag)	Bag	145	5.8	0.312	0.409	0.430
Potassium nitrate (25 kg/bag)	Bag	125	5.0	0.561	0.735	0.773
Magnesium sulphate (25 kg/bag)	Bag	75	3.0	0.357	0.468	0.492
Calcium nitrate (25 kg/bag)	Bag	80	3.2	0.741	0.971	1.021
Iron chelate 6% (1 kg/bag)	Bag	45	45.0	0.065	0.085	0.089
Copper (1 kg/bag)	Bag	45	45.0	0.009	0.011	0.012
Manganese (1 kg/bag)	Bag	45	45.0	0.050	0.065	0.068
Zinc (1 kg/bag)	Bag	40	40.0	0.008	0.010	0.011
Boron (1 L/bottle)	Bottle	35	35.0	0.020	0.026	0.028
Molybdenum (1 L/bag)	Bag	35	35.0	0.013	0.016	0.017
Phosphoric acid (20 L/container)	Container	150	7.5	0.054	0.054	0.054
Total				2.189	2.851	2.995

Table 8 Substrates and pots costs

Substrates	Substrate volume in liter per pot of 6 L				Substrate cost (AED/pot)	Pot cost (AED/pot)	Total cost (m^2)
	Sand	Peat moss	Gravel	Total			
2/3 sand + 1/3 peat	3.33	1.67	0.75	5.75	0.68	2.5	6.36
Price of substrate AED/L	0.037	0.3	0.075				

4.4 *Summary of Running Costs and Investment Depreciation*

Table 12 shows that the lowest production costs are corresponding to cucumber grown under net house. Costs related to labor were the highest among running cost (under subsidized energy scenario) especially for cherry tomato which requires a high level of conduct and maintenance. However cucumber does not require such as number of labor as its cropping practices are not requiring much care.

Table 9 Pesticides used quantity and equivalent costs

Pesticides	Unit price (AED/l)	Used pesticides quantity (ml)			Pesticides costs (AED)		
		Cucumber	Cherry tomato	Sweet pepper	Cucumber	Cherry tomato	Sweet pepper
Ouardin (insecticide)	100	125	200	175	0.04	0.07	0.06
Lorsban (insecticide)	100	125	200	175	0.04	0.07	0.06
Prefex (fungicide)	180	250	400	350	0.16	0.26	0.23
Prisma (insecticide)	220	125	200	175	0.10	0.16	0.14
Tina (acaricide)	220	125	200	175	0.10	0.16	0.14
Chlorpyriphos (insecticide)	85	82	132	115	0.03	0.04	0.04
Total (AED/m^2)					0.47	0.75	0.66

Table 10 Seeds and other costs

Costs	Cucumber	Cherry tomato	Sweet pepper
Seeds price (AED/grain)	0.36	0.9	0.2
Seeds costs (AED/m^2)	0.72	1.8	0.4
Other cost	0.34	0.56	0.41

Table 11 Energy use and costs under both greenhouse (cherry tomato and sweet pepper) and net house (cucumber) for both scenario (energy subsidized and not subsidized)

Energy consumption		Unit	Cucumber	Cherry tomato	Sweet pepper
Irrigation		l/m^2 CP[a]	432.2	627.4	659.5
Cooling		l/m^2 day	4.7	18.3	14.5
Cooling energy		Wh/m^2 day	10.4	332.0	268.2
Fresh water production energy		Wh/m^2 CP	1124	1631	1715
Irrigation energy		Wh/m^2 day	12.5	12.0	12.1
Energy subsidized	Irrigation and cooling energy cost	AED/m^2 CP	0.062	1.548	1.261
	Fresh water production energy cost	AED/m^2 CP	0.034	0.049	0.051
	Total energy cost	AED/m^2 CP	0.096	1.597	1.313
Energy not subsidized	Irrigation and cooling energy cost	AED/m^2 CP	0.515	12.898	10.511
	Fresh water production energy cost	AED/m^2 CP	0.281	0.408	0.429
	Total energy cost	AED/m^2 CP	0.796	13.306	10.940

[a]Cropping period

Table 12 Summary of running costs and investment depreciation

Crops	Cucumber	Cherry tomato	Sweet pepper
Labors	2.52	8.40	4.20
Fertilizers	2.19	2.85	3.00
Pesticides	0.47	0.75	0.66
Substrates and pots	1.92	2.19	2.19
Others	0.34	0.56	0.41
Energy (subsidized)	0.096	1.597	1.313
Energy (not subsidized)	0.80	13.31	10.94
Seeds	0.72	1.80	0.40
Running costs (energy subsidized)	8.26	18.15	12.17
Running costs (energy not subsidized)	8.96	29.86	21.80
Investment depreciation	3.56	7.03	7.03
Total (energy subsidized)	11.81	25.18	19.20
Total (energy not subsidized)	12.51	36.88	28.82

4.5 *Benefice*

According to Table 13 the highest net benefice based on one cropping period is corresponding to cherry tomato followed by sweet pepper and this due to mainly to their high market price compared to cucumber and the subsidized energy. However the highest net benefice based on the whole year production (where cucumber can be produced 3 times during the year) is corresponding to cucumber. Those numbers indicate that producing cucumber under net house with 3 cropping periods allowed to maximize the farmer benefice compared to cherry tomato under greenhouse and

Table 13 Yield, market price, turnover and net benefice

<table>
<tr><th colspan="2">Crops</th><th>Cucumber</th><th>Cherry Tomato</th><th>Sweet pepper</th></tr>
<tr><td colspan="2">Yield (kg/m^2)</td><td>9.35</td><td>8.38</td><td>8.78</td></tr>
<tr><td colspan="2">Price (AED/kg)</td><td>2.50</td><td>4.75</td><td>3.51</td></tr>
<tr><td colspan="2">Total turnover (AED/m^2)</td><td>23.37</td><td>39.79</td><td>30.82</td></tr>
<tr><td rowspan="4">Energy subsidized</td><td>Total cost (AED/m^2)</td><td>11.81</td><td>25.18</td><td>19.20</td></tr>
<tr><td>Net benefit (AED/m^2)</td><td>11.56</td><td>14.61</td><td>11.62</td></tr>
<tr><td>Net benefit (AED/ha)</td><td>104,038</td><td>131,519</td><td>104,598</td></tr>
<tr><td>Net benefit for the whole year</td><td>312,114</td><td>263,037</td><td>209,196</td></tr>
<tr><td rowspan="4">Energy not subsidized</td><td>Total cost (AED/m^2)</td><td>12.51</td><td>36.88</td><td>28.82</td></tr>
<tr><td>Net benefit (AED/m^2)</td><td>10.86</td><td>2.90</td><td>1.99</td></tr>
<tr><td>Net benefit (AED/ha)</td><td>97,736</td><td>26,141</td><td>17,955</td></tr>
<tr><td>Net benefit for the whole year</td><td>293,208</td><td>52,283</td><td>35,910</td></tr>
</table>

further more save water and energy. In case of not subsidized energy the greenhouse is not rentable as the energy cost increase the total cost and reduce the net benefice. Cucumber production under net house remains very profitable even if energy is not subsidized and allows to earn more than 5 and 8 times compared to cherry tomato and sweet pepper grown under greenhouse.

5 Discussion

It has been shown that greenhouse farming system performed better than the open farming system in terms of crop yield, irrigation water productivity and fruit quality. The results revealed that the crop evapotranspiration inside the greenhouse matched the 75–80% of the crop evapotranspiration computed with the climatic parameters observed in the open environment (Harmanto et al. 2005). Under desert conditions as the case of UAE greenhouse cooling is a must in order to produce especially during the summer season (May-September). However cooling process consume a considerable amount of water and energy especially the pad-fan system widely used in UAE and GCC countries. Our results indicates that cooled greenhouse consume 4 times more cooling water than net house. Whereas there is no significant difference between irrigation water consumption. Obtained results for tomato irrigation water consumption (5.23 mm/day) confirm the finding reported by Harmanto et al. (2005) who showed that tomato actual water consumption under greenhouse conditions was about 5.6 mm/day.

According to Franco et al. (2014) the main drawback of the pad-fan system was the horizontal temperature gradients, with a maximum difference of 11.4 °C between the pads and the fans. According to López et al. (2012) the fog system required higher energy consumption (7.2–8.9 kWh) than the pad-fan system (5.1 kWh) for continuous operations over 1 h. If we assume, based on López et al. (2012) that the fogging system in the net house was operating 20 s per 5 min, it means 36 min during 10 h. Thus the energy consumed during the day for fogging system is equal to 4.32 kWh/day. While the cooled greenhouse during summer season is operating continuously with a total energy consumption of 122 kWh/day, which means that the cooled greenhouse consume about 28 time more energy compared to fogging system. Our results indicate that the greenhouse consumes 32 time energy compared to net house equipped with fogging system which confirm the results obtained by López et al. (2012). Canakci and Akinci (2006) analyzed energy use pattern in greenhouse for vegetable. They found that the operational energy and energy source requirements in greenhouse vegetable production were varying from 23,883.5 to 28,034.7 and 45,763.3 to 49,978.8 MJ/1000 m^2, respectively. The energy cost ratio from total production cost of four major greenhouse vegetable crops—such as tomato, pepper, cucumber, and eggplant- was found about 0.32, 0.19, 0.31, 0.23, respectively which confirm our finding where energy cost (not subsidized) represent 0.36 and 0.37 of total running cost for tomato and sweet pepper respectively. However energy cost ration in the case of cucumber under net house does not exceeds 0.06.

A study aimed to determine the cost and return of soilless greenhouse cucumber has been carried out by Engindeniz and Gül (2009) in Turkey. The study reported that total production cost was equal to 3.47 USD/m^2 which is in agreement with our finding, where cucumber production cost was equal to 11.81 AED/m^2, equivalent to 3.21 USD/m^2. However the net benefit reported by Engindeniz and Gül (2009) is equal to 1.84 USD/m^2 although the total yield was equal to 31 kg/m^2. However in our case net benefit was equal to 3.14 USD/m^2 with a total yield of 9.35. This difference in terms of benefit is explained by the lowest market price of 0.17 USD in Turkey compared to 0.68 USD/kg in UAE.

6 Conclusion

Giving the current situation of water resources and energy aggravated by climate change in UAE as well as GCC countries, cooled greenhouse is not a sustainable option for horticultural crops production. It was shown that this protected agriculture system consumes a considerable amount of water and energy in cooling process. However UAE climate allows to produce a large number of fruits and vegetables crops between October and May, that is a total of 8 months with a mild climate. During this period horticultural crops can be grown under net house even without cooling allowing, thus, increasing crop water productivity, energy saving and income improvement. Agricultural policies such as subsidized energy leads to use more cooled greenhouse rather than encouraging sustainable protected agriculture as net house for better water and energy saving. Therefore, there is a need to improve energy and water use efficiency in the protected agriculture in GCC region and to reduce the water and energy footprint under protected agriculture in GCC region.

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