

# Cost Benefit Analysis of Growing Cucumbers in Greenhouse at Different Cooling of Nutrient Solution Temperatures in Closed Hydroponic System in Oman

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## Abstract

Oman is a country that is mostly dry and hot, with daily maximum temperatures easily reaching 40 °C or more during summer. The Oman weather therefore renders conventional open field agriculture almost impossible. The sustainable future of agriculture in Oman and other similar desert countries will therefore depend very much on the adoption of land and water saving technologies such as greenhouses and soilless culture or hydroponics. Soilless culture (Hydroponics) is the technique of growing plants without soil with their roots immersed in nutrient solution. Among factors affecting hydroponic production systems, is the nutrient solution temperature which is considered to be one of the most important determining factors of crop yield and quality. The aim of this research is therefore to investigate the economic effect of cooling nutrient solutions temperature technique on cucumber output. Four nutrient solutions temperatures are investigated and a Cost Benefit Analysis is undertaken. Results indicate that all the four cooling nutrient temperature yields positive returns (benefits) above variable and total costs for the two years of this experiment. Cooling nutrient temperature (22 °C) yields higher returns than the other treatments followed by treatment (25 °C), (28 °C) and then the CONTROL treatment. Returns for the second year are higher than the first year. Therefore treatment (22 °C) was observed to be the best overall producing the highest return above variable and total costs. It is therefore considered the best alternative for cucumber growers.

**Keywords:** cost, benefit, greenhouse, cucumber, cooling solution, soilless culture

## 1. Introduction and Background

Cucumber cultivation in greenhouses currently plays a very important role in Oman and other desert countries. In fact, this will continue to be so, as vegetable growing in a controlled environment continues to expand in these countries. This is because one of the most serious constraints facing agriculture in Oman and other desert countries include shortage of land and suitable water for agriculture. Oman is a country that is mostly dry and hot, with daily maximum temperatures temperature easily reaching 40 °C or more during summer. Winters are cooler with occasional rainfalls. However, in spring and summer seasons a hot, and dusty wind (the Shamal), blows making it very hot and unbearable. To overcome this, farmers have historically resorted to digging wells and pumping water in order to carry out farming. With time, this has however proved to be unsustainable and destructive because it has resulted into sea water intrusion and hence soil salinity especially in the Batinah coast. The Oman weather therefore renders conventional open field agriculture almost impossible. As highlighted in Mbaga (2013; 2014) and (Mbaga et al., 2018) as well as by a number of other authors on this subject matter, the sustainable future of agriculture in Oman and other similar desert countries will depend very much on the adoption of land and water saving technologies such as greenhouses and soilless culture or hydroponics. Soilless culture (Hydroponics) is the technique of growing plants without soil with their roots immersed in nutrient solution (Maharana and Koul, 2011). Among factors affecting hydroponic production systems, is the nutrient solution temperature which is considered to be one of the most important determining factors of crop yield and

quality. The temperature of the nutrient solution influences the uptake of water and nutrients differentially by the crop (Maharana and Koul, 2011). There are a wide range of research works done over the years on the combinations of these technologies with very promising results e.g., Al-Helal, (2007); Al-Helal and Al-Hamdan, (2009); Al-Ismaili and Jayasuriya, (2016) and Al-Ismaili et al., (2018). Farmers using hydroponic system in greenhouses to grow vegetables in Oman face the challenge of high temperature of nutrient solution in feeding tanks especially in summer season when temperatures reach above 40 degrees centigrade. The aim of this research work is therefore to investigate the economic effect of cooling nutrient solutions temperature technique on cucumber output. The four nutrient solutions temperatures are: (i) Treatment 1 (22 °C), (ii) Treatment 2 (25 °C), (iii) Treatment 3 (28 °C) and (iv) Treatment 4 (33 °C) as CONTROL.

## 2. Materials and Methods.

The experiments were conducted in a cooled greenhouse of dimension 30 m long x 9 m wide at the Directorate General of Agriculture and Livestock Research in Rumais, Barka around 40 km north of capital Muscat during three periods of growing cucumber under hydroponics viz., summer temperature period (June-August), fall temperature period (September-November) and spring temperature period (February-May) for two years during 2016/ 2017 and 2017/2018. We investigate the economic effect on cucumber output at three Root-Zone Temperatures (Hereafter RZT) of cooling nutrient solution viz. RZT1 (22°C), RZT2 (25°C) and RZT3 (28°C). Besides the three RZT we have the control-uncooled nutrient solution RZT4 (33°C) that had root-zone ambient temperature of over 33°C. The experiment was arranged in Randomized Complete Design (RCD) with four replications. Each temperature treatment was equipped with cooling system connected with electricity meter in order to record the power consumption during the course of the experiment. Appendices I and II present raw data in terms of cost of materials (cooling system and stock solution), labour, power consumption per treatment and cucumber output (yield kg/GH) for each of the three cropping period (June-August, September-November and February-May) in a year. The experiment was carried out over a period of two years 2016/2017 (Appendix I) and 2017/2018 (Appendix II). In both years 1 and 2 cucumber price was high during cropping period (June-August) at 0.400 Baiza, as compared to 0.200 Baiza for September-November and February-May cropping periods. Greenhouse Investment Costs (Fixed Costs) for Cucumber Production for this experiment is as indicated in Table 1 below. As in other similar studies such as: Smith et.al. 1990; Sengar, and Kothari, (2008); and Chito, (2007) we assume here that contract labor is used to construct the greenhouse. Straight line depreciation approach is used on all items. The depreciation period for each item is as shown in Table 1. An interest charge of 9% is made to the average investment (half the initial cost) of each item as in previous studies above. Taxes and insurance are assumed to be 1.25% of the original investment.

Table 1. Greenhouse Investment Costs (Fixed Costs) for Cucumber Production in Oman

Construction	Original cost	Life Yrs	Depr.	Interest**	Tax + Insur*	Annual maint. Cost	Annualized
1. Construction cost of cooling system for one temp. treatment	239.000	5	47.800	10.755	2.988	10.000	71.543
2. Costs of channels	160.000	5	32.000	7.200	2.000	0.000	41.200
3. Cost of labor for installation	200.000	5	40.000	9.000	2.500	0.000	51.500
4. Cables DP outside to DP inside GH	45.000	5	9.000	2.025	0.563	0.000	11.588
5. Cables DP inside GH to coolers	7.500	5	1.500	0.338	0.094	0.000	1.931
Total Constr. Cost	651.500		130.300	29.318	8.144	10.000	177.761

Note: \*Taxes and Insurance rate % = 1.3. Currency is in Rial Oman (RO) ≈ 2.58 US\$

\*\* Interest rates % = 9

As presented on Table 1 above the construction costs of a cooled greenhouse of dimension 30 m long x 9 m wide used for this experiment amounted to RO 651.500. The depreciation costs are RO130.300, Interest charges are RO29.318, Tax and Insurance costs are RO8.144 and Annual maintenance costs are RO10.00. As a result, the annualized costs (amount to be charged each year on the enterprise in relation to initial investment costs) are RO. 177.761.

## 3. Results and Discussion

Based on the data presented in Appendix I and Appendix II, the variable costs associated with each of the four (4) treatments RZT (22°C), RZT (25°C), RZT (28°C) and the control RZT (33°C) were calculated for the two years for which this experiment was undertaken. The results are as presented in Table 2 (Year one) and Table 3 (Year two).

The Total Variable Costs for year one are RO. 862.79, RO. 859.09, RO. 848.39 and RO. 839.19 for RZT (22 °C), RZT (25 °C), RZT (28 °C), RZT (33 °C) respectively. Therefore the Total Variable Costs for RZT (22 °C) were the highest and the Total Variable Costs for Treatment 4 (33 °C) were the lowest. RZT (22 °C) consumed more power than the other three treatments.

Table 2. Total Variable Costs per Treatment Year One

VARIABLE COSTS				
RZT (22 °C)	June - Aug	Sept - Nov	Feb-May	Annual VAR. COST
Labor	180.00	180.00	180.00	540.00
Seeds	50.00	50.00	50.00	150.00
Chemicals	33.33	33.33	33.33	99.99
Cost of stock solution	16.40	16.40	16.40	49.20
Power	10.60	6.00	7.00	23.60
Total Variable Costs RZT (22 °C)				862.79
RZT (25 °C)	June - Aug	Sept - Nov	Feb-May	Annual VAR. COST
Labor	180.00	180.00	180.00	540.00
Seeds	50.00	50.00	50.00	150.00
Chemicals	33.33	33.33	33.33	99.99
Cost of stock solution	16.40	16.40	16.40	49.20
Power	9.50	5.40	5.00	19.90
Total Variable Costs RZT (25 °C)				859.09
RZT (28 °C)	June - Aug	Sept - Nov	Feb-May	Annual VAR. COST
Labor	180.00	180.00	180.00	540.00
Seeds	50.00	50.00	50.00	150.00
Chemicals	33.33	33.33	33.33	99.99
Cost of stock solution	16.40	16.40	16.40	49.20
Power	5.80	1.80	1.60	9.20
Total Variable Costs RZT (28 °C)				848.39
CONTROL				
RZT (33 °C)	June - Aug	Sept - Nov	Feb-May	Annual VAR. COST
Labor	180.00	180.00	180.00	540.00
Seeds	50.00	50.00	50.00	150.00
Chemicals	33.33	33.33	33.33	99.99
Cost of stock solution	16.40	16.40	16.40	49.20
Total Variable Costs CONTROL RZT (33 °C)				839.19

Table 3. Total Variable Costs per Treatment Year Two

VARIABLE COSTS				
RZT (22 °C)	June - Aug	Sept - Nov	Feb-May	Annual VAR. COST
Labor	180.00	180.00	180.00	540.00
Seeds	50.00	50.00	50.00	150.00
Chemicals	33.33	33.33	33.33	99.99
Cost of stock soln.	16.40	16.40	16.40	49.20
Power	10.60	6.10	8.80	25.50
Total Variable Costs RZT (22 °C)				864.70
RZT (25 °C)	June - Aug	Sept - Nov	Feb-May	Annual VAR. COST
Labor	180.00	180.00	180.00	540.00
Seeds	50.00	50.00	50.00	150.00
Chemicals	33.33	33.33	33.33	99.99
Cost of stock solution	16.40	16.40	16.40	49.20
Power	9.60	5.60	5.20	20.40
Total Variable Costs RZT (25 °C)				859.60
RZT (28 °C)	June - Aug	Sept - Nov	Feb-May	Annual VAR. COST
Labor	180.00	180.00	180.00	540.00
Seeds	50.00	50.00	50.00	150.00
Chemicals	33.33	33.33	33.33	99.99
Cost of stock solution	16.40	16.40	16.40	49.20
Power	5.80	1.80	2.44	10.04
Total Variable Costs RZT (28 °C)				849.23
CONTROL Treatment 4				
RZT (33 °C)	June - Aug	Sept - Nov	Feb-May	Annual VAR. COST
Labor	180.00	180.00	180.00	540.00
Seeds	50.00	50.00	50.00	150.00
Chemicals	33.33	33.33	33.33	99.99
Cost of stock solution	16.40	16.40	16.40	49.20
Total Variable Costs CONTROL RZT (33 °C)				839.19

As indicated in Table 3 above results for this experiment in the second year produced a comparable pattern in that the Total Variable Costs for RZT (22 °C) were the highest and the Total Variable Costs for RZT (33 °C) were the lowest. Similarly, RZT (22 °C) consumed more power than the other three treatments.

Table 4. Seasonal and Annual Revenue per Treatment Year One

Treatments	June - Aug	Sept - Nov	Feb-May	Annual revenue
RZT (22 °C)	2,000.00	1,280.00	1,540.00	4,820.00
RZT (25 °C)	1,760.00	1,400.00	1,600.00	4,760.00
RZT (28 °C)	1,880.00	1,200.00	1,160.00	4,240.00
RZT (33 °C) CONTROL	1,120.00	1,000.00	1,120.00	3,240.00

Table 5. Seasonal and Annual Revenue per Treatment Year Two

Treatments	June - Aug	Sept - Nov	Feb-May	Annual revenue
RZT (22 °C)	2,440.00	1,700.00	1,700.00	5,840.00
RZT (25 °C)	2,400.00	1,740.00	1,520.00	5,660.00
RZT (28 °C)	1,520.00	1,400.00	1,420.00	4,340.00
RZT (33 °C) CONTROL	1,400.00	1,360.00	1,300.00	4,060.00

With regard to revenue, seasonal and annual revenue per treatment for year one and year two are as presented in Table 4 and Table 5 above respectively. Apparently RZT (22 °C) registered highest annual revenue at RO. 4,820.000 during the first year whereas RZT (33 °C) produced the lowest annual revenue at RO 3,240.000.

Similarly during the second year, RZT (22 °C) registered highest annual revenue at RO. 5,840.000, whereas RZT (33 °C) produced the lowest annual revenue at RO 4060.000. Second year annual revenues were higher across all

four (4) Treatments.

The results of the analysis of the costs and benefits of the four (4) treatments across the three seasons and over the two years of this experiment are as presented in Table 6 and 7 below.

Table 6. Return Above Total and Variable Costs in Oman Rial per Treatment Year One

Item	RZT (22 °C)	RZT (25 °C)	RZT (28 °C)	RZT 33 °C
Revenue	4,820.00	4,760.00	4,240.00	3,240.00
Variable costs	849.71	846.01	835.31	789.99
Fixed costs	177.76	177.76	177.76	0.00
Return above variable costs	3,970.29	3,913.99	3,404.69	2,450.01
Return above total costs	3,792.53	3,736.23	3,226.93	2,450.01

Table 7. Return Above Total and Variable Costs in Oman Rial per Treatment Year Two

Item	RZT (22 °C)	RZT (25 °C)	RZT (28 °C)	RZT 33 °C
Revenue	5,840.00	5,660.00	4,340.00	4,060.00
Variable costs	851.61	846.51	836.15	789.99
Fixed costs	177.76	177.76	177.76	0.00
Return above variable costs	4,988.39	4,813.49	3,503.85	3,270.01
Return above total costs	4,810.63	4,635.73	3,326.09	3,270.01

As indicated in the last two rows of Table 6 and 7, all the returns above variable costs and returns above total costs for the two years of this experiment are positive and significantly high. Treatment RZT (22 °C) yields highest returns than the other three treatments. This is followed by treatment 2, 3 and then the CONTROL treatment. Returns for the second year are higher than the first year.

Table 8. Return Above Total Costs in Oman Rial per Treatment for Year One and Two

Treatments	Year 1	Year 2
RZT (22 °C)	3,792.53	4,810.63
RZT (25 °C)	3,736.23	4,635.73
RZT (28 °C)	3,226.93	3,326.09
RZT (33 °C) CONTROL	2,450.01	3,270.01

Table 8 above presents a summary of returns above total costs in Oman rials per treatment for the two years. As can be observed in Table 8 above all treatments across all the two years of this experiment yielded positive returns above total costs. Furthermore, RZT (22 °C) was observed to be the best of all producing the highest return above total costs of RO. 3,792.53 during the first year and RO. 4, 810.63 during the second year respectively. This means that cooling nutrient solution to a Root-Zone Temperature of 22°C (RZT 22°C) leads to a better economic effect on cucumber output and hence higher return for cucumber farmers.

#### 4. Conclusion

Cucumber cultivation in greenhouses currently plays a very important role in Oman and will continue to do so, as vegetable growing in a controlled environment continue to expand in this country. Because of the shortage of land and water, the success of agriculture in Oman depends very much on the adoption of land and water saving technologies such as greenhouses and soilless culture or hydroponics. Among factors affecting hydroponic production systems, is the nutrient solution temperature which is considered to be one of the most important determining factors of crop yield and quality. In this research we conduct the Cost Benefit Analysis of growing Cucumbers in greenhouses at different cooling temperature of nutrient solution in a closed hydroponic system. The four nutrient solutions temperatures investigated are: (i) RZT (22 °C), (ii) RZT (25 °C), (iii) RZT (28 °C) and (iv) RZT (33 °C) as CONTROL.

Results showed that all four cooling nutrient temperature yielded positive returns (benefits) above variable and total costs for the two years of this experiment. RZT (22 °C) yields highest returns than the other. This is followed by treatment 2, 3 and then the CONTROL treatment. Returns for the second year are higher than the first year. Therefore, RZT (22 °C) was observed to be the best of all producing the highest return above variable and total costs of RO. 3,970.29 and 3,792.53 during the first year and RO. 4,988.39 and RO. 4, 810.63 during the second year respectively.

At this juncture, pending further experiments at the farm level (Farmer's field) at different regions of the country, results obtained here suggests that cooling solutions at 22 degree centigrade (22 °C) should be adopted by farmers in Oman as it leads to increased yield and hence more benefits to farmers.

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### Appendix I

First year 2016/2017 cost

Cost of cooling system for one temperature treatments

s	Item	quantity	Unit	Unit price O.R	Total price O.R
1	Cooling coil pipe 1/2 "	15	Meter	15	15
2	Cooling coil pipe 1/4"	15	Meter	8	8
3	Insulation slaves	12	No	0.250	3
4	Digital temperature control	1	No	20	20
5	Antistatic paint	1	No	5	5
6	Conductors 30A single phase	1	No	8	8
7	Isolator switch	1	No	5	5
8	Compressor unit 18000 BTU (1.5)	1	No	160	160
9	Control panel box	1	No	15	15
	Grand total O.R				239

Depreciation every year is 20% of cooling system unit

Maintenance every year cost 10 O.R

Cost of stock solution for each treatment per Season

Fertilizer	Price in O.R/ 25 Kg	Quantity used at each time	Price of quantity used at each time	Price in each season O.R
NPK 12:120:36	19	3 kg	2.28x2	4.56
Ca(NO3)	8	3 kgx2	1.92x2	3.84
MgSo4	11	1.5 kgx2	1.32x2	2.64
Iron Chilate	5	100 gx2	0.5x2	1.00
Nitric acid	44/20 liter	2liters	4.4	4.4
Total				16.4

Hint: each treatments prepared same amount of fertilizers used

- Cost of channels = 160 O.R One time
- Cost of labor for insulation = 2x10x 1 day = 20x10 days= 200 O.R
- Cost of labor for culture practice= 2 rials per labor /day (3 months/season) = 360
- Cost of Seeds (1000 seeds) = 50 O.R/season
- Cost cables:
  - 1- from Dp outside to Dp inside Gh = 10m each meter 4.5 O.R = 4.5x10m = 45 O.R
  - 2- From Dp inside Gh to coolers 15m 90m cost 45 O.R---15X45/90= 7.5 O.R
- Cost of chemicals: 100 O.R

Power consumption for each temperature per season:

Summer Season (June-August) first year 2016/2017

Treatments	At planting time	End of season	Consumption kw/season	Price per/kw O.R	Total price O.R
T1(22°C)	00884	01939	1055	0.01	10.6
T2(25°C)	00696	01649	953	0.01	9.5
T3(28°C)	00217	00798	581	0.01	5.8

Fall Season (Sept-Nov) first year 2016/2017

Treatments	At planting time	End of season	Consumption kw/season	Price per/kw O.R	Total price O.R
T1(22°C)	01988	02583	595	0.01	6.0
T2(25°C)	01703	02245	542	0.01	5.4
T3(28°C)	00823	01005	182	0.01	1.8

Spring Season (Feb-May) first year 2016/2017

Treatments	At planting time	End of season	Consumption kw/season	Price per/kw O.R	Total price O.R
T1(22°C)	00001	00696	695	0.01	7
T2(25°C)	00155	00655	500	0.01	5
T3(28°C)	00060	00217	157	0.01	1.6

Production of cucumber and price/season for first year 2016/2017

RZTs	June-August			September-November			February-May		
	Yield kg/gh	Price /kg O.R	Total income O.R	Yield kg/gh	Price /kg O.R	Total income O.R	Yield kg/gh	Price /kg O.R	Total income O.R
T1 (22°C)	5000	0.4	2000	6400	0.2	1280	7700	0.2	1540
T2 (25°C)	4400	0.4	1760	7000	0.2	1400	8000	0.2	1600
T3 (28°C)	4700	0.4	1880	6000	0.2	1200	5800	0.2	1160
T4 (33°C)	2800	0.4	1120	5000	0.2	1000	5600	0.2	1120

## Second year 2017/2018 Cost

## Cost of stock solution for each treatment per Season

Fertilizer	Price in O.R/ 25 Kg	Quantity used at each time	Price of quantity used at each time	Price in each season O.R
NPK 12:120:36	19	3 kg	2.28x2	4.56
Ca(NO <sub>3</sub> )	8	3 kg x 2	1.92x2	3.84
MgSo <sub>4</sub>	11	1.5 kg x 2	1.32x2	2.64
Iron Chilate	5	100 gx 2	0.5x2	1.00
Nitric acid	44/20 liter	2liters	4.4	4.4
Total				16.4

Hint: each treatments prepared same amount of fertilizers used

- Cost of labor for culture practice= 2 rials per labor /day (3 months/season) = 360
- Cost of Seeds (1000 seeds) = 50 O.R/season
- Cost of chemicals: 100 O.R

Power consumption for each temperature per season:

## Summer Season (June-August) second year 2017/2018

Treatments	At planting time	End of season	Consumption kw/season	Price per/kw O.R	Total price O.R
T1(22°C)	00884	01654	1059	0.01	10.6
T2(25°C)	00696	01943	958	0.01	9.6
T3(28°C)	00217	00798	581	0.01	5.8

## Fall Season (Sept-Nov) second year 2017/2018

Treatments	At planting time	End of season	Consumption kw/season	Price per/kw O.R	Total price O.R
T1(22°C)	01988	02598	610	0.01	6.1
T2(25°C)	01703	02258	555	0.01	5.6
T3(28°C)	00823	01005	182	0.01	1.8

## Spring Season (Feb-May) second year 2017/2018

Treatments	At planting time	End of season	Consumption kw/season	Price per/kw O.R	Total price O.R
T1(22°C)	02598	003476	878	0.01	8.8
T2(25°C)	02258	002776	518	0.01	5.2
T3(28°C)	01005	01249	244	0.01	2.44

## Production of cucumber and price/season for second year 2017/2018

RZTs	June-August			September-November			February-May		
	Yield kg/gh	Price O.R /kg	Total income O.R	Yield kg/gh	Price O.R /kg	Total income O.R	Yield kg/gh	Price O.R /kg	Total income O.R
T1 (22°C)	6100	0.4	2440	8500	0.2	1700	8500	0.2	1700
T2 (25°C)	6000	0.4	2400	8700	0.2	1740	7600	0.2	1520
T3 (28°C)	3800	0.4	1520	7000	0.2	1400	7100	0.2	1420
T4 (33°C)	3500	0.4	1400	6800	0.2	1360	6500	0.2	1300

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