Agrico Qafco Yara Trial and Demonstration Center

Report on trials conducted on December 2019-December 2020

Compiled by
Karina Enikeeva, Yara International
Carol Khadra, Yara Internaitonal

Doha, Qatar

31.12.2019

Because of the specialist and experimental nature of the trials, the varieties of crops, grown in different production systems, on various soils, and under differing climatic conditions, Yara International, Qatar Fertilizer Company and Agrico disclaims all warranties, express or implied, as to the accuracy of trial results or any other information, costs and recommendations provided in the trial reports, and takes no liability for agronomic decisions based on this information. When using and relying on trial results and related material, you accept that you will take full responsibility for all agronomic decisions, results and yields

Contents

List of tables

List of Charts

List of Pictures

Executive Summary

Agrico for Agricultural Development, Qatar Fertiliser Company (QAFCO) and Yara International ASA (Norway) signed a Cooperation Agreement on the 15th of October 2018 to establish a Hydroponic Trial and Demonstration Center in Qatar to test local greenhouse technologies, nutrient management and best horticultural practices. The objective was to develop a sustainable crop management system suited for the Qatari climate that achieves high yields and productivity while conserving precious local water resources and limiting any negative impact of vegetables production on the local environment.

The Trial and Demonstration Center's growing Area is 3,750 square meters and was established on a plot near Agrico Farm in Al Khor. The Center was designed and built by Agrico using technology, knowledge and expertise accumulated during 10 years of experience operating in protected agriculture in Qatar. The Center is jointly operated by Agrico and Yara Agronomists while QAFCO gives full agricultural analytical support for substrate, water and leaves testing in the QAFCO Lab in Mesaieed.

The Trial and Demonstration Center features four different types of greenhouses:

- Low tech: Multispan greenhouse protected by insect net
- Mid tech tunnels: Plastic tunnels with evaporative cooling
- Mid tech multispan: Multispan plastic greenhouse with evaporative cooling
- Mid tech multispan with night cooling: Multispan plastic greenhouse with evaporative cooling and air-conditioning for night cooling

All crops in the Trial and Demonstration Center are grown in hydroponics, a method of growing fruits and vegetables without the use of natural soil. In soilless agriculture, crops are grown in substrate (for example coco coir, perlite, rock wool) that is constantly fed with nutrient solutions. This way of growing reduces the risk of plants being exposed to soil diseases and allows saving of water, fertilizers and agro-chemicals.

All plants are constantly fed with nutrient solution via a drip irrigation system that precisely combines water and required nutrients. The nutrient solution is prepared from Yara's fertilizers and is tailored for each crop and each stage of growth.

The results of the first season starting from December 11, 2019 till December 31, 2019 are the following:

Section	Type	Crop	Yield, kg/m2	Capital cost QAR/m2	Total Cost QAR/kg
Section 1	Mid tech multispan	Tomato	33.2	624	4.20
Section 2	Mid tech multispan	Tomato	29	534	4.47
Section 3	Mid tech tunnels	Cucumber	22.6	227	4.51
Section 4	Mid tech tunnels	Cucumbers	23.6	227	4.15

Section 5[1]	Mid tech tunnels	Tomatoes	18.6	227	3.83
Section 6	Mid tech tunnels	Tomatoes	18.5	227	3.85
Section 7	Low tech	Tomatoes	12	194	4.99

The main conclusion from the first season results is that it is possible to achieve higher than 30 kg/m2 productivity with technologies for greenhouses that are widely available in Qatar. However the methods, practices and farming capabilities determine success or failure of cultivation of fresh vegetables in Qatar. The use of hydroponics for cultivation of fresh vegetables in Qatar can bring significant improvements in yields and water utilisation however such method of cultivation requires special knowledge and experience of farmers to achieve the desirable results.

Therefore in order to increase the local production of fresh vegetables in a sustainable way the main focus of the industry regulators, investors and farm owners should be on the development of the applied knowledge and practices, attraction of highly skilled farmers and following the best practices in crop nutrition, fertigation, crop management and water management.

The Chapter 1 of the report describes the main objectives of the trials conducted at the Trial and Demonstration Center.

The Chapter 2 of the report gives the details of the infrastructure and the type of the greenhouses in the Trial and Demonstration Center.

The Chapter 3 of the report provides details and methods for cultivation of tomatoes.

The Chapter 4 of the report provides details and methods for cultivation of cucumbers.

The Chapter 5 and Chapter 6 provides detailed information on the cost of production and the amount of production by month in each section of the greenhouse.

In the appendices to the report two detailed protocols for preparing the grow bags for cultivation and tomato seeds germination.

[1] Section 5 and Section 6 were cultivated with tomatoes only from December 11, 2018 till June 2019

1. The main objectives of the trials

The objectives of the trials conducted at the Trial and Demonstration Center are:

1. To test local greenhouse technologies and provide the recommendations for improvement
2. To develop the nutrient management system most appropriate for the Qatari climate
3. To demonstrate the best practices in crop management methods
4. To achieve yields and productivity more than 50% higher than Qatar average yield for crops grown in similar greenhouses.
5. To train the local farming community

2. Description of the infrastructure

2.1. Greenhouses

The Trial and Demonstration Center's growing Area is 3,750 square meters and is established on a plot near Agrico Farm in Al Khor. The Center was designed and built by Agrico using technology, knowledge and expertise accumulated during 10 years of experience operating in protected agriculture in Qatar.

There are four different types of greenhouses in the Trial and Demonstration Center:

1. Mid Tech Multispan with night cooling : Multispan plastic greenhouse with shading, evaporative cooling and night air conditioning. The evaporative cooling in the greenhouse is comprised of fan and pad system which is part of a greenhouse's mechanical ventilation system. The maximum amount of cooling possible with evaporative cooling systems depends on the humidity of the air as well as the initial temperature of the air. The drier the initial air, the more water can be evaporated into it, and the more the final air temperature will drop. Therefore during high humidity period the cooling effect is low. Since it is important to keep the temperature inside of the greenhouse low during the night time in order to boost generative growth of plants, the air conditioning system is installed to provide cooling during humid nights. Such combination of passive and active cooling allows to extend the growing season in Qatar from end of May till end of July for such crops as tomatoes, cucumbers and sweet peppers.
2. Mid tech multispan: Multispan plastic greenhouse with shading, evaporative cooling only. Such system allows to cool the greenhouse when the outside humidity is relatively low. The growing season in such greenhouses is typically 10 months from September till end of June.

Picture 1: Multispan greenhouse with evaporative cooling

3. Mid tech tunnels: Plastic tunnels with shading and evaporative cooling. The growing season in this type may last to up to 10 months per year. Plastic tunnels are most appropriate for small scale farming.

Picture 2: Low tunnels with evaporative cooling (Mid tech tunnels)

4. Low tech: Multispan greenhouse protected by insect net. This is the most affordable type of greenhouses and suitable for growing vegetables for 10 months per year for winter crops. The growing season might be extended for summer crops like melons and okra

Picture 3: Multispan greenhouse protected by insect net (Low Tech)

Table 1: General properties of the different types of greenhouse

Type	Growing season	Recommended crops	Capex, QAR/m2
Mid Tech Multispan with night cooling: Plastic greenhouse with evaporative cooling and AC for night cooling	September-July	Tomatoes, Cucumbers, Sweet Peppers	624
Mid tech multispan: Plastic greenhouse with evaporative cooling	September – June	Tomatoes, Cucumbers, Sweet Peppers	534
Mid tech tunnels: Low tunnel with evaporative cooling	October-June	Tomatoes, Cucumbers, Sweet Pepers, Eggplants, Leafy greens, beans	227
Low tech: Multispan greenhouse protected by insect net	October-June	Tomatoes, Egg plants	194

Different types of greenhouses establish different climate. Plastic multispan greenhouses allow more sunlight; the larger volume of air inside of the greenhouse provides better aeration and greater temperature buffer inside of the greenhouses. The low tunnels allow less light and less aeration than multispan greenhouses however they provide favourable conditions when the outside temperature is bellow 35C. The greenhouse protected by an insect net allows less sunlight, less protection from wind and from sudden temperature changes.

The Trial and Demonstration Center was comprised of the following 7 sections:

Table 2: Sections of the Trial and Demonstration Center

Section	Type	Area, m2	Crop	Plant density
Section 1	Mid tech Multispan with night cooling	586	Tomatoes	3 plants/m2
Section 2	Mid tech multispan	630	Tomatoes	3 plants/m2
Section 3	Mid tech tunnels	315	Cucumbers	3 plants/m2
Section 4	Mid tech tunnels	315	Cucumbers	3 plants/m2
Section 5	Mid tech tunnels	315	Tomatoes	3 plants/m2
Section 6	Mid tech tunnels	315	Tomatoes	3 plants/m2
Section 7	Low tech	1260	Tomatoes	3 plants/m2

2.2. Growing media

All crops in all 7 Sections of the Trial and Demonstration Center are grown in hydroponics, a method of growing fruits and vegetables without the use of natural soil. In soilless agriculture, crops are grown in substrate (for example coco coir, perlite, rock wool) that is constantly fed with nutrient solutions. This way of growing reduces the risk of plants being exposed to soil diseases and allows saving of water, fertilizers and agro-chemicals. In addition yields in hydroponics are usually higher than in soil based cultivation, meaning more production using less land, fertilizers and water and the prevention of land contamination.

The growbags made of 100% coco substrate are used in the Center. The growbag is delivered as a dry plate in enclosed Panda Film. In order to prepare growing bags for planting it is necessary to flush growbags with water and Calcium nitrate solution. See 7.1 Coco peat grow bags leaching and buffering protocol (ref: HF003) for more details on methods to prepare grow bags for planting.

2.3. Fertigation system

The irrigation at the Trial and Demonstration Center is conducted via drip irrigation system managed by a centralized computer Xilema Fertigation produced by Novagric. The system allows automatic application of water with nutrients to the plants according to predefined schedules and recipes of fertilizers.

2.4. Climate measurement and control system

The climate in the trial and demonstration center was managed manually on the basis of the climate readings in each section of the greenhouse, amount of drainage water, electrical conductivity of the drainage and the state of the plants.

In sections 1-6 which are equipped with evaporative cooling, the climate was managed by turning on and off the fans and by changing the speed of the fans. When humidity inside of the greenhouse reaches more than 90% relative humidity (RH), then the fans work without allowing water to run through cooling pads to dry the environment inside of the greenhouse. That typically happens during the night and early mornings. Section 1-6 are equipped with shading screens. The screens are expanded when temperature in the greenhouse exceeds 35C and RH more than 80%. During summer time the screens are normally expanded between 11:00 and 13:00. During winter time the screens are usually collapsed.

2.5. Fresh water sources

The quality of the irrigation water is especially important in hydroponic systems and affects requirements for the composition of nutrient solutions. In soils, roots can obtain available nutrients from a larger root zone compared to hydroponic systems where the root growth is restricted by the limiting dimensions of the substrate, and will therefore suffer immediately when nutrient solutions are not adjusted to accommodate water quality. Since ground water in Qatar contains very high level of salts with EC of 5-20 mS/cm it is necessary to treat water before application to the plants. The water in the Trial and Demonstration Center is produced by a reverse osmosis plant where the ground water is purified and disinfected. The salinity of ground water is reduced from 15 mS/cm to 0.2 mS/cm.

Table 3: Composition of well water at Agrico

Charac-teristic	Unit	No.40 Agrico (Well water)
Ca	µmol/l	12575.0
Cu	µmol/l	<1
Fe	µmol/l	<1
K	µmol/l	3325.0
Mg	µmol/l	9918.0
Mn	µmol/l	<1
Mo	µmol/l	<1
Na	µmol/l	102218
P	µmol/l	4.5
S	µmol/l	26793.0
Zn	µmol/l	<1
As	µmol/l	<1
Cd	µmol/l	<0.5
Cr	µmol/l	<0.5
Pb	µmol/l	<0.5
Hg	µmol/l	<0.5
pH	µmol/l	7.10
EC	µS/cm	12800
Cl-	µmol/l	98730.6
NO3 as N	µmol/l	780.65
NH3 as N	µmol/l	32.1
HCO3	meq/l	3.56

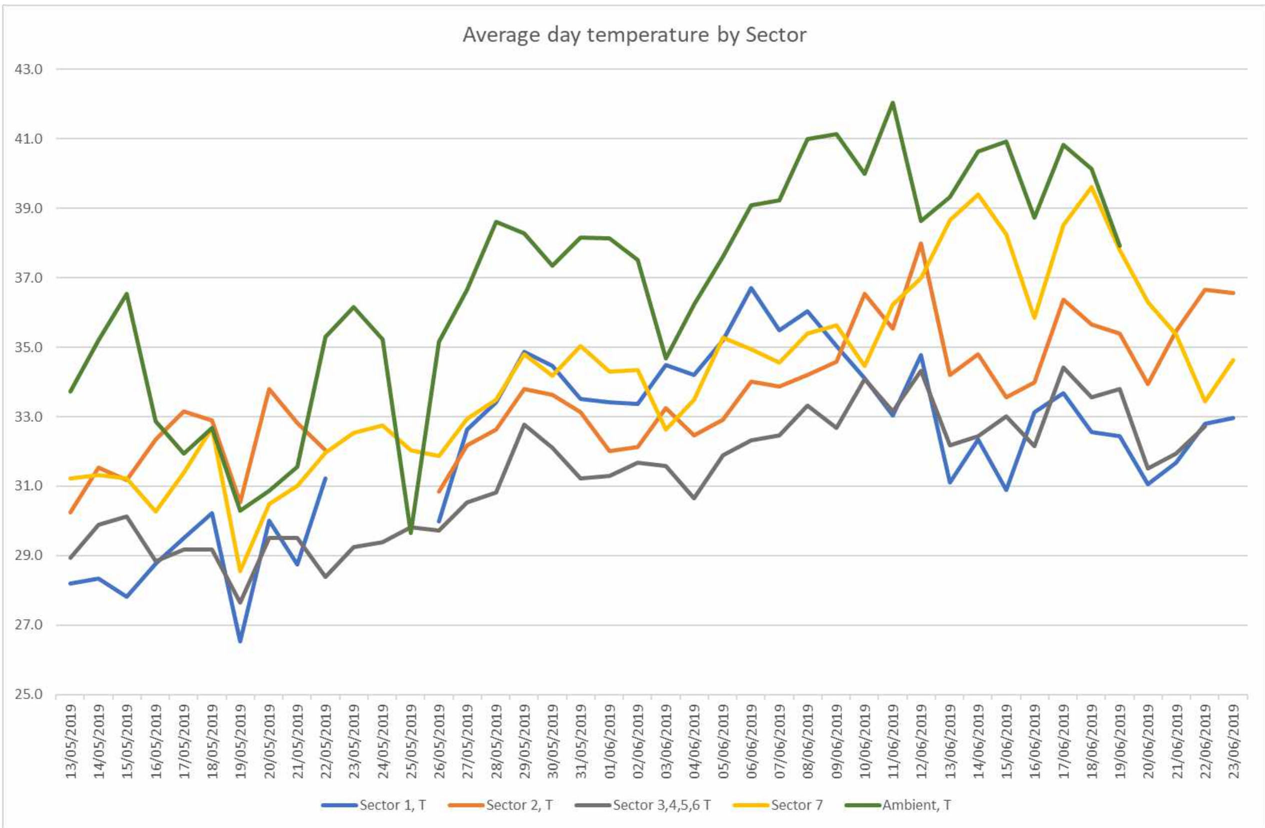
Table 4: Composition of RO water at Agrico

Charac-teristic	Unit	No.41 Agrico (RO water)
Ca	µmol/l	165.0
Cu	µmol/l	<1
Fe	µmol/l	<1
K	µmol/l	72.0
Mg	µmol/l	97.0
Mn	µmol/l	<1
Mo	µmol/l	<1
Na	µmol/l	1522
P	µmol/l	<1
S	µmol/l	140.0
Zn	µmol/l	<1
As	µmol/l	<1
Cd	µmol/l	<0.5
Cr	µmol/l	<0.5
Pb	µmol/l	<0.5
Hg	µmol/l	<0.5
pH	µmol/l	6.70
EC	µS/cm	260
Cl-	µmol/l	1698.2
NO3 as N	µmol/l	261.3
NH3 as N	µmol/l	38.6
HCO3	meq/l	0.64

2.6. Climate conditions achieved in each Section

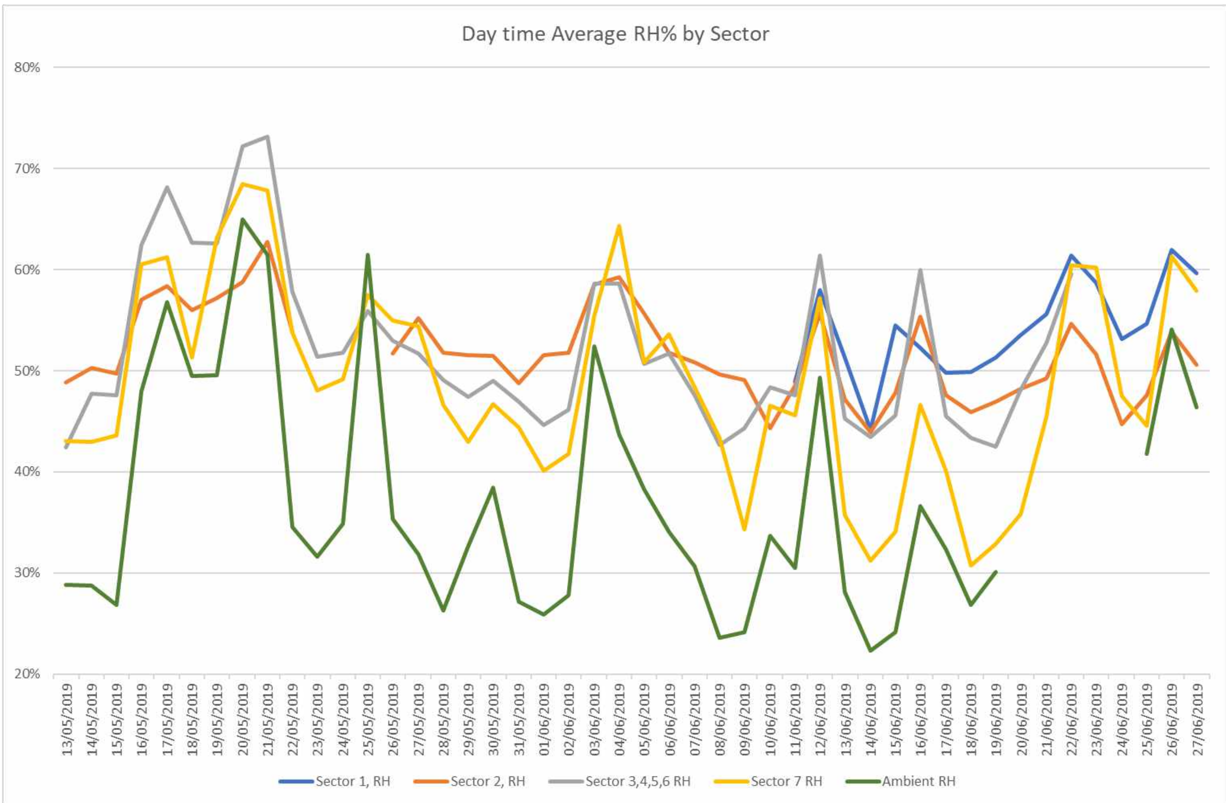
During the trial period the climatic data such as temperature and RH was collected in each Section of the Trial Center as well as outside, the ambient condition. For illustration the data for one month is presented on the charts to illustrate how temperature and RH were adjusted against the ambient conditions in each type of greenhouses.

Chart 1: Day time average daily temperature by Section



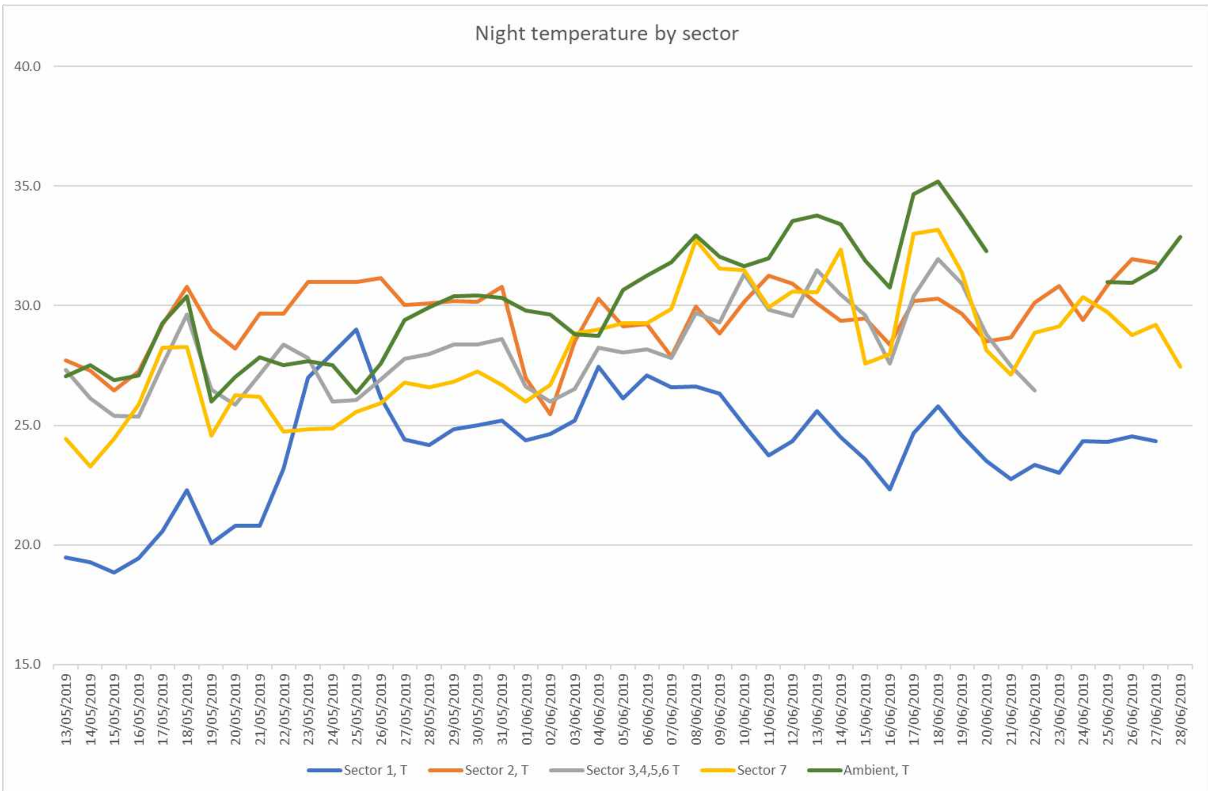
As it can be seen from the chart above every Section provides conditions to reduce temperature inside of the structure. As the ambient RH was low therefore the evaporative cooling system allowed to drop the temperature from the peak levels by 7-8 C in cooling tunnels. The cooling effect in Section 1 and Section 2 was lower probably due to insufficient cooling capacity for such a large area of the greenhouse. Better positioning of the ventilation pads and shortening the distance between the fans and the cooling pad wall might increase the efficiency of evaporative cooling.

Chart 2: Average day time relative humidity by Section



Humidity overall in all Sections was higher than ambient humidity as all structures provided certain micro climate for plants and allowed to keep the humidity inside of the structure. Evaporative cooling also increases RH in Section 1-6. However in all structures RH level wasn't higher than the appropriate RH level of 70-80% for healthy growth of the plants.

Chart 3: Average night time temperature by Section

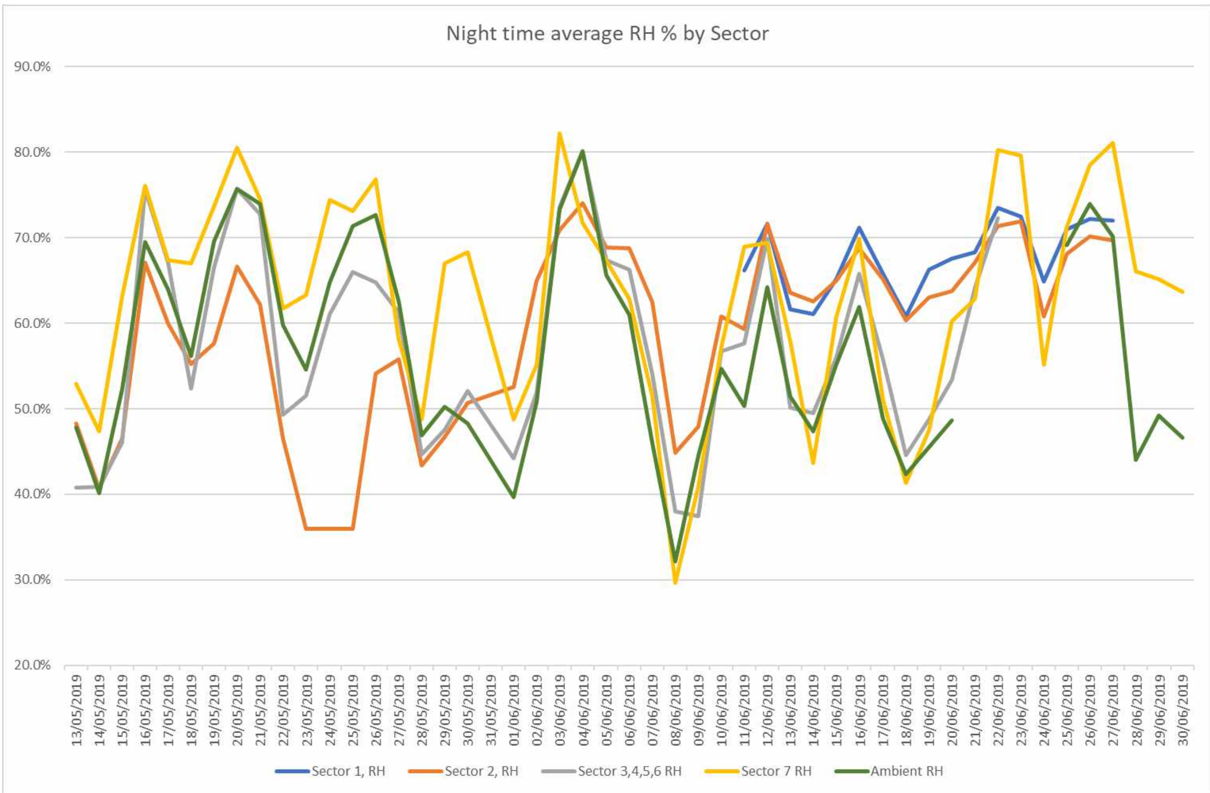


As Section 1 is equipped with the mechanical cooling system that was used during night time, the temperature in Section 1 was significantly lower than in other structures. In addition Section 2 didn't provide better environment for night time temperature management and most of the time was warmer than cooling tunnels. The shade net temperature followed the ambient temperature however still provided a few degrees cooler environment.

Knowledge grows

QAFCO
قافكو
شركة قطر للأسمدة الكيماوية
QATAR FERTILISER COMPANY

Chart 4: Average night time relative humidity by Section



3. Tomato cultivation

3.1. The main parameters of tomato plantation and achieved productivity

Five Sections of the Trial and Demonstration Center were planted with tomatoes. There were several varieties of tomatoes planted:

Table 5: Varieties of tomatoes planted

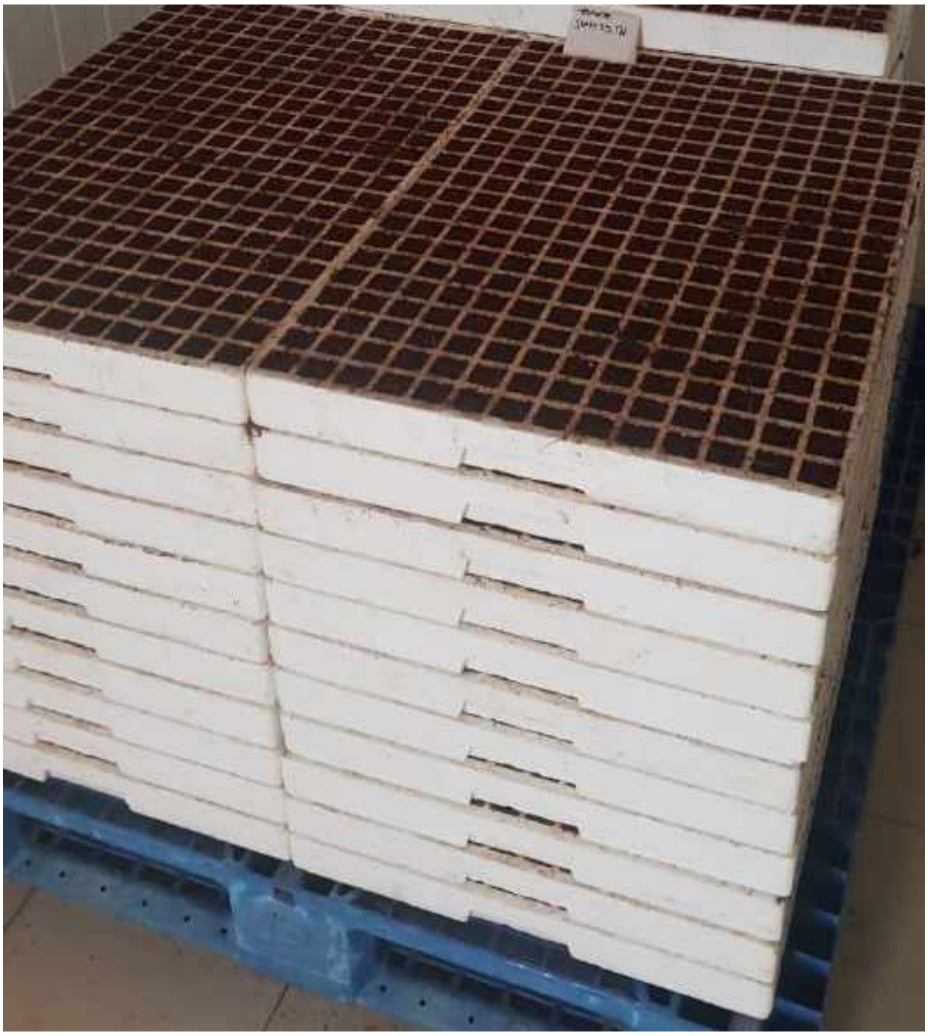
Section	Variety	Plantation
Section 1	Seminis SV4129TH	95%
Section 1	Enza Zaden Elpida, Naram	5%
Section 2	Seminis SV4129TH	95%
Section 2	Enza Zaden Elpida, Naram	5%
Section 5	Seminis SV4129TH	100%
Section 6	Seminis SV4129TH	100%
Section 7	Seminis SV4129TH	90%
Section 7	Enza Zaden, Elpida, Naram	10%

3.2. Germination and seedling production

Germination is the process of seeds developing into new plants and is an important first step in the whole cultivation cycle of any crop. Several factors influence if, and how, seeds germinate. The most important factors are water availability, temperature, sunlight and hygiene during germination and seedling production. Access to a clean germination room and nursery facilities is essential. See the detailed germination and seedling production protocol in 7.2 Tomato seeds germination protocol (ref. HF002).

The germination of tomato seeds for the trials was started on 06/11/2019. The seedlings were transferred from germination trays into seedling cubes on 22/11/2019. The seedlings were nursed for 25 days according to the procedure explained in the protocol HF002 and transplanted into greenhouses on 11/12/2018.

Picture 4: Germination trays with tomato seeds, November 06



Picture 5: Tomato seedlings, November 12

Picture 6: Tomato seedlings, November 22

Picture 7: Tomato seedling in nursery, November 26

The seedlings were transplanted into the greenhouse on December 11, 2018. The procedure took place in the afternoon when the intensity of the solar radiation is low in order to avoid burning of young plants.

Other aspects to consider after transplantation are integrity of the irrigation system (dripper are connected to every single plant), irrigation regime, EC of drip water and light intensity.

Due to certain limitations in the nursery where the seedlings were produced the stems of the plants were elongated and the thickness was less than required. First 7 days drip EC was set to EC 1.5ms/cm, next 7 days to 2, next 7 days to 2.6. More light (by avoiding shading) and less water allowed to thicker the stems. The stem thickness defines the ability of plants to transfer nutrients

Picture 8: Transplanted tomato seedlings in Section 1, December 11, 2018

3.3. Fertigation and nutrient management system

The nutrient management system for cultivation of tomatoes in the Trial and Demonstration Center was designed according to Yara's standards on nutrients requirements published in Nutrient Solutions for Greenhouse Crops, Version 3, 2017. https://cdnmedia.eurofins.com/corporate-eurofins/media/12142795/160825_manual_nutrient_solutions_digital_en.pdf

The nutrients requirements for a given crop depends on the composition of fresh water used for irrigation, the type of the substrate and the stage of the plant development. The water composition was provided in Fresh water sources, page 12. For undetermined tomatoes cultivated in protected environment 5 growth stages are identified for different nutrition regimes.

All required nutrients are sourced from the following fertilizers:

- YaraLiva Calcinit (15.5-0-0) is a fully water soluble nitrogen and calcium fertilizer (calcium nitrate) containing 15.5% of nitrogen and 19% of calcium, chloride free.

- YaraTera Kristalon: It is a range of multi-nutrient water soluble fertilizers that contains best quality macro, secondary and micronutrients, free from Urea, have very low sodium and chloride levels.
- YaraTera KRISTALON is designed for high value crops and fertigation systems with products serving every growth stage, for all systems. For tomatoes two kinds of Kristalon were used:
    - YaraTera Kristalon Brown (3-11-38), that contains 3% of nitrogen in the form of nitrates, 11% of P2O5 (or 4.8% of Phosphorus), 38% of K20 (or 31.5% of Potassium), 4% of MgO (or 2.4% of magnesium), 11% of Sulfur.
    - YaraTera Kristalon Red (12-12-36), that contains 10.1% of nitrogen in the form of nitrates and 1.9% of ammonia, 12% of P2O5 (or 5.2% of Phosphorus), 36% of K20 (or 30% of Potassium), 1% of MgO (or 0.6% of magnesium), 1% of Sulfur.
    - YaraTera Kristalon Scarlet (7.5-12-36) that contains 7.5 % of nitrogen in the form of nitrates, 12% of P2O5 (or 5.2% of Phosphorus), 36% of K20 (or 30% of Potassium), 4.5% of MgO (or 2.7% of magnesium), 4% of Sulfur. It also contains Fe-DTPA and FE-EDTA.
- YaraTera Krista MgS is a water soluble fertilizer containing 16% of MgO and 32.5% of SO3.
- Iron Chelates Yara Vita Tenso Fe EDDHMA 6%.

The following fertigation recipe was developed for the first growth stage of tomatoes from the start till the 3rd cluster.

Table 6: Tomatoes fertigation recipe from start to 3rd cluster

General Fertigation Advice
Adjust recommendation to suit local conditions.

This advice is valid till: 12/25/2018
After this date take a sample of the root enviroment and adjust the recommendation.

Crop : Tomato Cocolcoir. Start till start flowering 3rd cluster.
Name : Agrico Qatar
Remark :
Date: 12/11/2018

Growth medium: Coco/coir	Macro nutrients concentration in mmol/l										Micro nutrients concentration in µmol/l						
	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	Cl^-	SO_4^{2-}	$H_2PO_4^-$	H_3O^+	Urea	Fe	Mn	Zn	B	Cu	Mo	EC mS/cm
Standard nutrient solution	0.70	8.00	6.20	2.60	16.00		4.40	1.50			25.00	10.00	5.00	30.00	0.75	0.50	2.63
Correction according growth stage		-1.00	0.50	0.50	1.00												
Manual correction																	
Result at temporary EC 2.75	0.70	7.00	6.70	3.10	17.00		4.40	1.50			25.00	10.00	5.00	30.00	0.75	0.50	2.73
Deviation																	
Desired recipe at EC 2.63	0.70	6.74	6.45	2.98	16.38		4.24	1.45			25.00	10.00	5.00	30.00	0.75	0.50	2.63
Input of raw water	-0.04	-0.07	-0.17	-0.27	-0.26		-0.14	-0.01	0.64								-0.11
Desired fertiliser solution	0.66	6.46	6.08	2.63	15.76		4.01	1.44	0.64		25.00	10.00	5.00	30.00	0.75	0.50	2.52
Result of fertiliser mix	1.25	6.46	6.22	2.34	15.40		4.30	1.24			25.00	5.82	3.06	18.50	1.26	0.33	2.50
Deviation	88%	0%	2%	-11%	-2%		7%	-14%				-42%	-39%	-38%	68%	-33%	

CHECK Final result

Tank size: 1000 litre. Concentration: 100 x for: 100000 litre final plant solution

TANK A		TANK B	
Calcinit	134.4 kg	Krista MgS	36.2 kg
		Kristalon Brown 3+11+38+4	60 kg
Fe EDDHMA 6%	1394 g		

All specifications of the formulas are in oxide form.

Acid in Tank A + B
No acid

Acid harms chelates
If dripwater pH > 6: high risk of clogging

Ratio to N = 1 mmol/l	N total	P / N	K / N	Mg / N	Ca / N	Ca / K
Desired ratio	16.4 mmol/l	0.09	0.39	0.16	0.37	0.94
Result in solution	16.8 mmol/l	0.07	0.39	0.14	0.37	0.96

(Greenhouse) soil fertigation	N standard	Correction	drip +25%	N total	EC setting (mS/cm)
N dose in mmol/l					

total input of raw water	Macro nutrients concentration in mmol/l										Micro nutrients concentration in µmol/l						EC in mS/cm
	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	NO_3^-	Cl-	S	P	HCO_3^-	Urea	Fe	Mn	Zn	B	Cu	Mo	
100% raw water	0.04	0.07	0.17	0.27	1.52	0.26	1.70	0.14	0.01	0.64								0.24
Total nutrient solution	1.29	6.52	6.39	2.61	1.52	15.66	1.70	4.44	1.24	0.64		25.00	5.82	3.06	18.50	1.26	0.33	2.70

The optimal EC depends of daily weather, crop, EC growth medium, etc.

IMPORTANT:
Check the pH and EC of the nutrient solution and root enviroment several times per week.

The mother solution was prepared by diluting 134.4 kg of Calcinit and 1.394kg of Iron chelates in tank A and 36.2 kg of Kristal MgS and 60 kg of Kristalon Brown in Tank B. To apply nutrients to the plants the nutrients get diluted with water in proportion 100x in the irrigation machine to achieve electrical conductivity (EC) of 2.7 mS/cm of the final drip water which is applied to the plants.

Picture 9: Manual measuring of Ph of drip water for tomatoes

Picture 10: Manual measuring of EC of drip water for tomatoes

Daily monitoring of electrical conductivity (EC) and Ph of fresh water, drip water, drain water is required to maintain the most optimum nutrient regime and to avoid salinity stress to the plants. Maintaining Ph level within the range of 5.5-6.5 is necessary to ensure that the plants absorb the most optimal amount of nutrients from the solution and the nutrients don't interact in the solution and there is no precipitation and clogging.

Table 7: EC and Ph measurements on May 20, 2019

	Drip water EC, mS/cm	Drain Water EC, mS/cm	RO water EC, mS/cm	Drip water PH	Drain Water PH	RO water PH	Drain Water, %
Section 1&2	2.5	2.9	0.67	5.5	6.2	6.47	35%
Section 3&4	1.4	1.8	0.67	6.1	6.7	6.47	30%

Section 5&6	2.5	3.2	0.67	5.6	5.7	6.47	32%
Section 7	2.1	5.2	0.67	5.5	6.4	6.47	28%

On May 20 the following readings of EC and Ph of fresh, drip and drain water were taken by using manual EC and Ph meters. Drip water EC in all Sections were according to the requirements of the fertigation regime for each Section.

When deciding on number of irrigation cycles the general recommendation is to provide irrigation at least 4 times per day between sunrise and sunset. The duration of irrigation cycles determines amount of water applied. Amount of water applied has to depend on the amount of drainage from the grow bag. In coco peat bags the target drainage amount after each irrigation cycle should be around 30%. However the first two irrigation cycles give almost no drainage as the grow bags are dry after the night when no irrigation is given.

In the trial station the following fertigation regime was maintained except for the days when the weather conditions were exceptional such as rain, high wind and extremely low humidity, low radiation.

Table 8: Fertigation schedule

Recipe	Start Date	Number of irrigation cycles	Minutes per cycle	Amount of water per cycle, l/m2	Total water applied daily, l/m2
Start to 3rd cluster	11.12.2018	4	6	0.6	2.4
3rd - 5th cluster	31.12.2018	5	8	0.8	4.0
5th-10th cluster	04.02.2019	7	8	0.8	5.6
10th -12th cluster	20.03.2019	7	8	0.8	5.6
12th to the end	30.05.2019	7	8	0.8	5.6

Table 9: Tomatoes fertigation recipe from 3rd to 5th cluster

General Fertigation Advice

Adjust recommendation to suit local conditions.

This advice is valid till: 1/29/2019
After this date take a sample of the root enviroment and adjust the recommendation.

Crop : Tomato Peat. Flowering 3rd to 5th cluster.
Name : Agrico Qatar
Remark :
Date: 1/15/2019

Growth medium: Peat	Macro nutrients concentration in mmol/l										Micro nutrients concentration in µmol/l						
	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	Cl^-	SO_4^{2-}	$H_2PO_4^-$	H_3O^+	Urea	Fe	Mn	Zn	B	Cu	Mo	EC mS/cm
Standard nutrient solution	1.50	10.00	5.00	2.40	16.00		4.40	1.50			15.00	10.00	5.00	30.00	0.75	0.50	2.63
Correction according growth stage		0.50	-0.13	-0.13													
Manual correction																	
Result at temperary EC 2.63	1.50	10.50	4.88	2.28	16.00		4.40	1.50			15.00	10.00	5.00	30.00	0.75	0.50	2.63
Deviation																	
Desired recipe at EC 2.63	1.50	10.50	4.88	2.28	16.00		4.40	1.50			15.00	10.00	5.00	30.00	0.75	0.50	2.63
Input of raw water	-0.04	-0.07	-0.17	-0.08	-0.25		-0.14	-0.01	0.64								-0.07
Desired fertiliser solution	1.46	10.03	4.83	2.11	15.81		4.20	1.50	0.64		15.00	10.00	5.00	30.00	0.75	0.50	2.54
Result of fertiliser mix	1.60	9.94	4.84	2.29	15.41		4.19	2.02			15.78	9.16	4.81	29.11	1.98	0.52	2.58
Deviation	9%	-1%	3%	8%	-1%		0%	35%			5%	-8%	-4%	-3%	164%	5%	

CHECK Final result

Tank size: 1000 litre. Concentration: 100 x for: 100000 litre final plant solution.

TANK A		TANK B	
Calcinit	100.9 kg	Krista MgS	34.8 kg
		Kristalon Brown 3+11+38+4	76.6 kg Fe-DTPA
		Kristalon Red 12+12+36+1	49.3 kg
Fe EDDHMA 6%	0 g		

All specifications of the formulas are in oxide form

Acid in Tank A + B: No acid

Acid harms chelates
If dripwater pH > 6: high risk of clogging.

Ratio to N = 1 mmol/l	N total	P / N	K / N	Mg / N	Ca / N	Ca / K
Desired ratio	17 mmol/l	0.09	0.60	0.12	0.27	0.45
Result in solution	17 mmol/l	0.12	0.58	0.13	0.27	0.47

(Greenhouse) soil fertigation	N standard	Correction	drip +25%	N total	EC setting (mS/cm)
N dose in mmol/l					

total input of raw water	Macro nutrients concentration in mmol/l										Micro nutrients concentration in µmol/l						EC in mS/cm
	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	NO_3^-	Cl-	S	P	HCO_3^-	Urea	Fe	Mn	Zn	B	Cu	Mo	
100% raw water	0.04	0.07	0.17	0.08	1.52	0.26	1.70	0.14	0.01	0.64								0.22
Total nutrient solution	1.64	10.02	4.81	2.37	1.52	15.67	1.70	4.33	2.02	0.64		15.78	9.16	4.81	29.11	1.98	0.52	2.74

The optimal EC depends of daily weather, crop, EC growth medium, etc.

IMPORTANT:
Check the pH and EC of the nutrient solution and root enviroment several times per week.

Agrico Qatar Tomato Peat. Flowering 3rd to 5th cluster.

Disclaimer The information herein contained is to the best of Yara knowledge and belief accurate. The conditions of your use and application of the suggested formulations and recommendations, are beyond our control. The recommendations are intended as a general guide and must be adapted to suit local conditions. No warranty is made as to the accuracy of any data or statements contained herein. Yara specifically disclaims any responsibility or liability relating to the use of the suggested formulations and recommendations and shall not in any event, be liable for any special, incidental or consequential damages arising from such use.

Table 10: Tomatoes fertigation recipe, 5th to 10th cluster

General Fertigation Advice

Adjust recommendation to suit local conditions.

This advice is valid till: 3/21/2019
After this date take a sample of the root enviroment and adjust the recommendation.

Crop : Tomato Peat. Flowering 5th to 10th cluster.
Name : Agrico Qatar
Remark :
Date: 3/7/2019

Growth medium: Peat	Macro nutrients concentration in mmol/l										Micro nutrients concentration in µmol/l						
	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	Cl^-	SO_4^{2-}	$H_2PO_4^-$	H_3O^+	Urea	Fe	Mn	Zn	B	Cu	Mo	EC mS/cm
Standard nutrient solution	1.50	10.00	5.00	2.40	16.00		4.40	1.50			15.00	10.00	5.00	30.00	0.75	0.50	2.63
Correction according growth stage		1.75	-0.63	-0.25													
Manual correction																	
Result at temperary EC 2.63	1.50	11.75	4.38	2.15	16.00		4.40	1.50			15.00	10.00	5.00	30.00	0.75	0.50	2.63
Deviation																	
Desired recipe at EC 2.63	1.50	11.75	4.38	2.15	16.00		4.40	1.50			15.00	10.00	5.00	30.00	0.75	0.50	2.63
Input of raw water	-0.00	-0.21	-0.61	-0.42	-0.12		-0.89	-0.00	0.70								-0.11
Desired fertiliser solution	1.50	11.10	3.62	1.66	15.50		3.43	1.50	0.70		15.00	10.00	5.00	30.00	0.75	0.50	2.39
Result of fertiliser mix	1.78	11.00	3.87	1.71	15.29		3.37	2.27			17.58	10.21	5.36	32.46	2.21	0.58	2.41
Deviation	19%	-1%	7%	3%	-1%		-2%	52%			17%	2%	7%	8%	194%	17%	

CHECK Final result

Tank size: 1000 litre. Concentration: 100 x for: 100000 litre final plant solution.

TANK A		TANK B	
Calcinit	83.6 kg	Krista MgS	21.4 kg
		Kristalon Brown 3+11+38+4	60.1 kg Fe-DTPA
		Kristalon Red 12+12+36+1	74.2 kg
Fe EDDHMA 6%	0 g		

All specifications of the formulas are in oxide form

Acid in Tank A + B: No acid

Acid harms chelates
If dripwater pH > 6: high risk of clogging.

Ratio to N = 1 mmol/l	N total	P / N	K / N	Mg / N	Ca / N	Ca / K
Desired ratio	17 mmol/l	0.08	0.68	0.10	0.21	0.33
Result in solution	17.1 mmol/l	0.13	0.64	0.10	0.23	0.35

(Greenhouse) soil fertigation	N standard	Correction	drip +25%	N total	EC setting (mS/cm)
N dose in mmol/l					

total input of raw water	Macro nutrients concentration in mmol/l										Micro nutrients concentration in µmol/l						EC in mS/cm
	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	NO_3^-	Cl-	S	P	HCO_3^-	Urea	Fe	Mn	Zn	B	Cu	Mo	
100% raw water	0.00	0.21	0.61	0.42	5.00	0.12		0.89	0.00	0.70								0.40
Total nutrient solution	1.78	11.22	4.48	2.13	5.00	15.41		4.26	2.28	0.70		17.58	10.21	5.36	32.46	2.21	0.58	2.66

The optimal EC depends of daily weather, crop, EC growth medium, etc.

IMPORTANT:
Check the pH and EC of the nutrient solution and root enviroment several times per week.

Agrico Qatar Tomato Peat. Flowering 5th to 10th cluster.

Disclaimer The information herein contained is to the best of Yara knowledge and belief accurate. The conditions of your use and application of the suggested formulations and recommendations, are beyond our control. The recommendations are intended as a general guide and must be adapted to suit local conditions. No warranty is made as to the accuracy of any data or statements contained herein. Yara specifically disclaims any responsibility or liability relating to the use of the suggested formulations and recommendations and shall not in any event, be liable for any special, incidental or consequential damages arising from such use.

Table 11: Tomatoes fertigation recipe, 10th to 12th cluster

General Fertigation Advice
Adjust recommendation to suit local conditions.

This advice is valid till: 4/3/2019
After this date take a sample of the root enviroment and adjust the recommendation.

Crop : Tomato Coco/coir. Flowering 10th to 12th cluster
Name : Agrico Qatar
Remark :
Date: 3/20/2019

Growth medium: Coco/coir	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	Cl^-	SO_4^{2-}	$H_2PO_4^-$	H_3O^+	Urea	Fe	Mn	Zn	B	Cu	Mo	EC mS/cm
	Macro nutrients concentration in mmol/l										Micro nutrients concentration in µmol/l						
Standard nutrient solution	0.70	8.00	6.20	2.60	16.00		4.40	1.50			25.00	10.00	5.00	30.00	0.75	0.50	2.63
Correction according growth stage		0.50	-0.13	-0.13													
Manual correction																	
Result at temperary EC 2.63	0.70	8.50	6.08	2.48	16.00		4.40	1.50			25.00	10.00	5.00	30.00	0.75	0.50	2.63
Deviation																	
Desired recipe at EC 2.63	0.70	8.50	6.08	2.48	16.00		4.40	1.50			25.00	10.00	5.00	30.00	0.75	0.50	2.63
Input of raw water	-0.00	-0.21	-0.61	-0.42	-0.12		-0.89	-0.00	0.70								-0.11
Desired fertiliser solution	0.70	7.98	5.26	1.98	15.50		3.43	1.50	0.70		25.00	10.00	5.00	30.00	0.75	0.50	2.39
Result of fertiliser mix	1.05	7.98	5.25	2.03	15.31		3.38	1.64			25.00	9.17	4.03	24.39	1.14	0.42	2.37
Deviation	51%	0%	0%	3%	-1%		-1%	9%				-8%	-19%	-19%	51%	-15%	

Tank size: 1000 litre. Concentration: 50 x for: 50000 litre final plant solution.

TANK A		TANK B		
Calcinit	56.7 kg	Krista MgS	11.8 kg	
		Kristalon Brown 3+11+38+4	25.3 kg	Fe-DTPA
		Kristalon Scarlet 7,5+12+36+	24.5 kg	Fe-DTPA/ED
Fe EDDHMA 6%	246 g			

All specifications of the formulas are in oxide form.

Acid in Tank A + B: No acid

Acid harms chelates
If dripwater pH > 6: high risk of clogging.

Ratio to N = 1 mmol/l	N total	P / N	K / N	Mg / N	Ca / N	Ca / K
Desired ratio	16.2 mmol/l	0.09	0.49	0.12	0.32	0.66
Result in solution	16.4 mmol/l	0.10	0.49	0.12	0.32	0.66

(Greenhouse) soil fertigation	N standard	Correction	drip +25%	N total	EC setting (mS/cm)
N dose in mmol/l					

total input of raw water	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	NO_3^-	Cl-	S	P	HCO_3^-	Urea	Fe	Mn	Zn	B	Cu	Mo	EC in mS/cm
	Macro nutrients concentration in mmol/l											Micro nutrients concentration in µmol/l						
100% raw water	0.00	0.21	0.61	0.42		0.12		0.89	0.00	0.70								0.21
Total nutrient solution	1.05	8.20	5.87	2.45		15.43		4.27	1.64	0.70		25.00	9.17	4.03	24.39	1.14	0.42	2.61

The optimal EC depends of daily weather, crop, EC growth medium, etc.

IMPORTANT:
Check the pH and EC of the nutrient solution and root environment several times per week.

Agrico Qatar Tomato Coco/coir Flowering 10th to 12th cluster

Disclaimer The information herein contained is to the best of Yara knowledge and belief accurate. The conditions of your use and application of the suggested formulations and recommendations, are beyond our control. The recommendations are intended as a general guide and must be adapted to suit local conditions. No warranty is made as to the accuracy of any data or statements contained herein. Yara specifically disclaims any responsibility or liability relating to the use of the suggested formulations and recommendations and shall not in any event, be liable for any special, incidental or consequential damages arising from such use.

Table 12: Tomatoes fertigation recipe, 12th cluster till end

General Fertigation Advice
Adjust recommendation to suit local conditions.

This advice is valid till : 6/13/2019
After this date take a sample of the root enviroment and adjust the recommendation.

Crop : Tomato Coco/coir. Flowering 12th cluster till end
Name : Agrico Qatar
Remark :
Date: 5/30/2019

Growth medium: Coco/coir	$N\text{-}NH_4^+$	K^+	Ca^{2+}	Mg^{2+}	$N\text{-}NO_3^-$	Cl^-	S	P	H^+ mmol	N-Urea	Fe	Mn	Zn	B	Cu	Mo	EC mS/cm
	Macro nutrients concentration in mg/l										Micro nutrients concentration in mg/l						
Standard nutrient solution	19	[illegible]	[illegible]	[illegible]	[illegible]		141	47			1.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Correction according growth stage																	
Manual correction		[illegible]	[illegible]														
Result at temperary EC 2.63	19	[illegible]	[illegible]	[illegible]	[illegible]		141	47			1.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Deviation																	
Desired recipe at EC 2.63	19	[illegible]	[illegible]	[illegible]	[illegible]		141	47			1.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Input of raw water	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	0.70								[illegible]
Desired fertiliser solution	10	256	235	51	217		110	46	0.70		1.40	0.56	0.33	0.32	0.05	0.05	2.39
Result of fertiliser mix	17	258	242	43	210		120	39			1.40	0.33	0.20	0.20	0.08	0.03	2.36
Deviation	73%	1%	3%	-16%	-3%		10%	-16%				-40%	-37%	-37%	72%	-32%	

The optimal EC depends of daily weather, crop, EC growth medium, etc.

Tank size: 1000 litre. Concentration: 50 x.

TANK A		TANK B		
Calcinit	85 kg	Krista MgS	11.7 kg	
		Kristalon Brown 3+11+38+4	40.9 kg	Fe-DTPA
Fe EDDHMA 6%	586.3 g			

All specifications of the formulas are in oxide form.

Acid in Tank A + B: No acid

Acid harms chelates
If dripwater pH > 6: high risk of clogging.

N total	Ratio to N=1 mmol	P / N	K / N	Mg / N	Ca / N	Ca / K
227 mg/l = 16.2 mmol	Desired ratio	0.09	0.40	0.13	0.36	0.90
227 mg/l = 16.2 mmol	Result in solution	0.08	0.41	0.11	0.37	0.91

(Greenhouse) soil fertigation	N standard	Correction	drip +25%	N total	EC setting (mS/cm)
N dose in mg/l					

total input of raw water	$N\text{-}NH_4^+$	K^+	Ca^{2+}	Mg^{2+}	Na^+	$N\text{-}NO_3^-$	Cl-	S	P	HCO_3^-	N-Urea	Fe	Mn	Zn	B	Cu	Mo	EC in mS/cm
	Macro nutrients concentration in mg/l											Micro nutrients concentration in mg/l						
100% raw water	8	8	25	10		2		29	0	43								0.21
Total Nutrient solution	17	266	266	53		212		149	39	43		1.40	0.33	0.20	0.20	0.08	0.03	2.60

IMPORTANT:
Check the pH and EC of the nutrient solution and root environment several times per week.

File name: Agrico Qatar Tomato Coco/coir Flowering 12th cluster till end

Disclaimer The information herein contained is to the best of Yara knowledge and belief accurate. The conditions of your use and application of the suggested formulations and recommendations, are beyond our control. The recommendations are intended as a general guide and must be adapted to suit local conditions. No warranty is made as to the accuracy of any data or statements contained herein. Yara specifically disclaims any responsibility or liability relating to the use of the suggested formulations and recommendations and shall not in any event, be liable for any special, incidental or consequential damages arising from such use.

3.4. Water use

One of the main objectives of the trial and demonstration center was to figure out the best fertigation regime that would allow the most effective use of water for irrigation. In addition to irrigation the fresh water was used for cooling as all Sections of the Trial and Demonstration center are equipped with evaporative cooling system. During the trials the following consumption of water was identified.

Table 13: The use of water for irrigation and cooling in different sections of the Trial and Demonstration center and comparison with typical consumption of water by farmers in Qatar

	Irrigation	Cooling	Yield	Water used
	liter/m2/day	liter/m2/day	kg/m2	liter/kg of produce
Typical practice in Qatar (in soil, open space or in greenhouses)[2]	8.0	0.0	5.0	384.0
Trial station, shade net	5.0	0.0	12.5	144.0
Trial station, cooling tunnels	5.0	6.0	18.5	214.1
Trial station, Multispan greenhouse with cooling	5.0	6.0	33.0	120.0

As the amount of water used for irrigation and cooling is determined by the area of cultivation and not by the amount of produce, the higher productivity ensures the better water utilisation ratio. As it shown in the table cooling requires more water than irrigation. Therefore from water utilisation point of view it is very critical to make sure that the productivity in cooled greenhouses is significantly higher than in open field to rationalize the use of additional amount of water for cooling.

3.5. Climate management

In order to achieve the maximum production it is important to provide the optimal climate environment for the plants. The climate is determined by the temperature, relative humidity and solar radiation inside of the greenhouse.

For tomato plants the most optimal growing climate conditions are:

Day time when solar radiation >0 and plants are in light reaction cycle of photosynthesis:

- Temperature 25C
- Radiation 200-600W/m2
- Humidity 80%

Night time when solar radiation =0 and plants are in dark reaction cycle of photosynthesis:

- Temperature 18C
- Humidity 85%

The climate in the greenhouses with cooling and shading can be adjusted to aim for the optimum parameters by shading, varying the speed of ventilation fans and switching on and off the flow of

[2] Typical consumption of water by vegetable farmers in Qatar is taken on the basis of Yara's knowledge about a typical set up of the irrigation system, type of irrigation equipment used, time of irrigation per day

water through the evaporative pad walls. High outside relative humidity reduces the potential for evaporative cooling and therefore lower the control over the climate in the greenhouse. Bellow is the table of recommended actions in the greenhouse with evaporative cooling (Section 2) depending on the outside weather conditions.

Table 14: Climate adjustments for different weather conditions

Radiation	Temperature	Humidity	Recommended actions
<400 W/m2	<25C	<50%	Keep shades retracted, run fans with cooling pads on low speed to increase humidity inside
<400 W/m2	<25C	>50%	Shades retracted, run fans without cooling pads for ventilation only
<400 W/m2	<25C	bellow 80%	Keep shades open, run fans without cooling pads for ventilation only
>400 W/m2	<25C	Bellow 80%	Close shades, run fans without cooling pads for ventilation only
<400 W/m2	25C-45C	Bellow 40%	Keep shades retracted, run fans with evaporative cooling. The speed of the fans depends on the achieved temperature in the greenhouse. The higher the speed the lower the temperature inside

3.6. Pest control

Qatar nature and climate conditions provide a perfect environment for a wide variety of insects and fungus. The insect pressure increases with hot weather when plants already struggle to survive. This makes them more susceptible to diseases. At the same time the plants that are strong and healthy and are fed with a balanced nutrients solution are more resistant to diseases.

It is important to choose the appropriate crop variety that is resistant to the most common diseases. In the trial station three variety of tomatoes were cultivated: Seminis SV4129TH, Enza Zaden Elpida and Enza Zaden Naram. Both varieties from Enza Zaden were not resistant to TYLCV. By the start of the harvest 30% of the plants affected by the virus were removed.

Table 15: Pesticides and their effect on the pests

Treatment\Diseases	White fly	Leaf minor	Warms and caterpillars	Red spider	Thrips	Aphids	Alternaria	Late blight	Downy/ Powdery mildw
Equatio Pro							x	x	x
Revus Top							x	x	x
Amistar Top							x	x	x
Evisect	x	x			x				
Sumi Alpha									
Coragen		x	x						
Avaunt Indoxacarb			x						

Mospilan 100g Nippon Soda	x		x		x	x			
Vertimec		x	x						
Decis (Deltrametrin 10%)	x		x			x			
Oberon SC 240				x					
Floramite SC				x					
Tracer (Spinosad 45% Sc)		x	x		x				
Sivanto	x					x			

3.7. Crop management, monitoring and maintenance

Tomato plants require constant monitoring and maintenance. The following are the most important aspects to consider:

3.7.1. Training of tomato plants

Undetermined tomato plants may reach the length of up to 18 meters in the right conditions. Since the growth and new fruits develop on the top of the plant it is important to have the right crop support system that would allow to grow the plant and expose the top of the plant to the sun shine.

When the first cluster is fully set it is necessary to start inclining the plants in order to define the direction of the truss in order not to break it.

Picture 11 The truss direction of the inclined tomato plant

Picture 12: Training tomato plants

3.7.2. Pollination

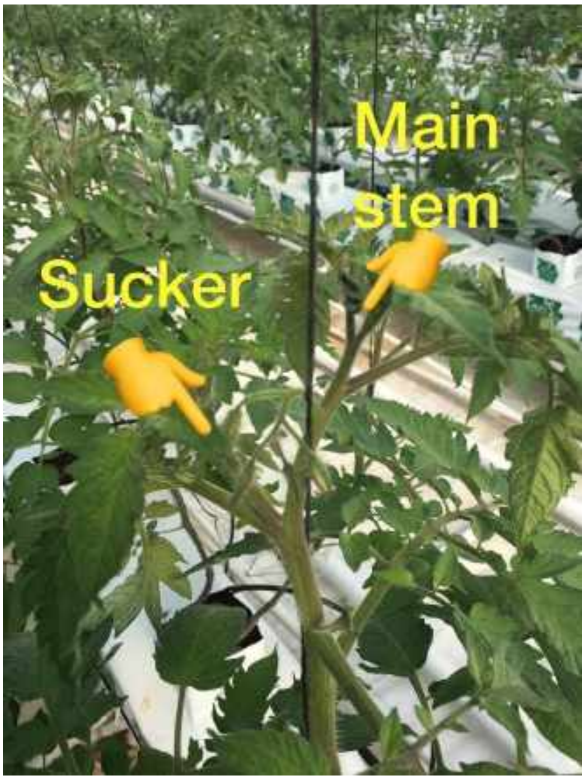
Pollination of the tomato is one of the most important steps in tomato cultivation as without pollination there will be no new fruits and no new production. Pollination of tomato plants can be done manually or with the help of bumble bees. In the trial station a manual pollinator was used for pollination. In case of using manual pollinators it is very important to ensure proper pollination of each new cluster of tomatoes. It is not enough to shake the whole plant by moving the supporting wire. The pollinator provides vibration of required frequency that is most suitable for effective pollination of the flower and successful fruit set.

Picture 13: Manual tomato pollinator

3.7.3. Suckers removal

Tomato suckers or side shoots are the growths that appear in the junction between the stem and a branch of a tomato plant. When left to grow, tomato plant suckers will become another main stem with branches, flowers, fruit, and even more suckers of their own. It is necessary to remove suckers in order to maintain the main stem of the plant and allow energy of the plant to send on fruit development.

Picture 14: Side shoots (suckers) on a young tomato plant



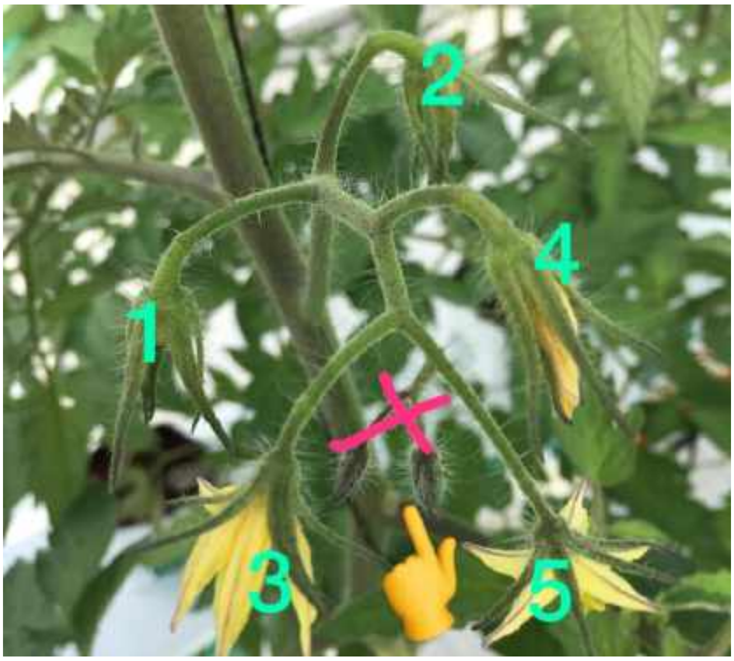
Suckers are very vigorous and tend to dominate the main stem if not removed timely. In addition suckers give flow clusters very quickly.

Picture 15: Training of the workers how to correctly remove suckers

3.7.4. Removing fruits, flowers and leaves

An undetermined tomato plant can carry about 40 fruits at the time. It is necessary to maintain the right amount of fruits per cluster to ensure the balanced size of fruits that leads to the best yield. In a chosen variety 4-5 plants is a right amount per cluster considering the density of plantation, amount of sunlight, the time of cultivation.

Picture 16: Maintaining the balanced number of fruits (4-5) per cluster



Maintenance of the right amount of leaves per plant is another aspect to be managed by the grower. On average around 15 leaves should be kept on the grown tomato plants. The old lower leaves need to be removed in order to maintain the right amount of vegetation and divert the energy of the plant on the development of the new clusters. The removal of lower leaves should be performed by sterilized instruments to prevent cross contamination of diseases.

3.7.5. Truss support

For the chosen variety of tomatoes the angle between the truss and main stem is low so when the fruits develop the truss base tend to bend or brake.

Picture 17: Use of supporting truss hooks to prevent bending of the truss when the angle between the truss and the main stem is low

Therefore the use of supporting truss hooks is essential to prevent bending the stem. If the stem is bended then the flow of water with nutrients to the fruits is limited and the fruits will not develop to its full potential.

4. Cucumber cultivation

4.1. The main parameters of cucumber planation and achieved productivity

Two low tunnels with evaporative cooling of the Trial and Demonstration Center were planted with cucumbers. There were several varieties of cucumbers planted:

Table 16: Varieties of cucumbers planted

Section	Plant density	Variety	Cultivation period
Section 3	3 plants/m2	Seminis Ourob	23 December – 23 April 2019
Section 4	3 plants/m2	Seminis Ourob	23 December – 23 April 2019
Section 3	3 plants/m2	Rijk Zwaan Beauty Sun BL	2 May - 26 July 2019
Section 4	3 plants/m2	Rijk Zwaan Beauty Sun BL	2 May - 26 July 2019
Section 3	3 plants/m2	Seminis Fenomeno	13 August – 9 November 2019
Section 4	3 plants/m2	Seminis Fenomeno	13 August – 9 November 2019

4.2. Fertigation and nutrient management system

The nutrient management system for cultivation of cucumbers in the Trial and Demonstration Center was designed according to Yara's standards on nutrients requirements published in Nutrient Solutions for Greenhouse Crops, Version 3, 2017. https://cdnmedia.eurofins.com/corporate-eurofins/media/12142795/160825_manual_nutrient_solutions_digital_en.pdf

The nutrients requirements for a given crop depends on the composition of fresh water used for irrigation, the type of the substrate and the stage of the plant development. The water composition was provided in Fresh water sources, page 12. For cucumbers cultivated in protected environment 2 growth stages are identified for different nutrition regimes – the vegetative and productive growth stages.

All required nutrients are sourced from the following fertilizers:

- YaraLiva Calcinit (15.5-0-0) is a fully water soluble nitrogen and calcium fertilizer (calcium nitrate) containing 15.5% of nitrogen and 19% of calcium, chloride free.
- YaraTera Kristalon: It is a range of multi-nutrient water soluble fertilizers that contains the best quality macro, secondary and micronutrients, free from Urea, have very low sodium and chloride levels.
- YaraTera KRISTALON is designed for high value crops and fertigation systems with products serving every growth stage, for all systems. For cucumbers two kinds of Kristalon were used:
  - YaraTera Kristalon Red (12-12-36), that contains 10.1% of nitrogen in the form of nitrates and 1.9% of ammonia, 12% of P2O5 (or 5.2% of Phosphorus), 36% of K20 (or 30% of Potassium), 1% of MgO (or 0.6% of magnesium), 1% of Sulfur.
  - YaraTera Kristalon Scarlet (7.5-12-36) that contains 7.5 % of nitrogen in the form of nitrates, 12% of P2O5 (or 5.2% of Phosphorus), 36% of K20 (or 30% of Potassium),

4.5% of MgO (or 2.7% of magnesium), 4% of Sulfur. It also contains Fe-DTPA and FE-EDTA.

- YaraTera Krista MgS is a water soluble fertilizer containing 16% of MgO and 32.5% of SO3.
- Iron Chelates Yara Vita Tenso Fe EDDHMA 6%.

Table 17: Cucumber fertigation recipe, Vegetative growth stage

General Fertigation Advice
Adjust recommendation to suit local conditions

This advice is valid till: 1/10/2019
After this date take a sample of the root enviroment and adjust the recommendation.

YARA

Crop : Cucumber. Coco peat. start BN
Name : Agrico Qatar
Remark :
Date 12/27/2018

Growth medium:	Macro nutrients concentration in mmol/l										Micro nutrients concentration in µmol/l						
	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	Cl^-	SO_4^{2-}	$H_2PO_4^-$	H_2O^-	Urea	Fe	Mn	Zn	B	Cu	Mo	EC mS/cm
Standard nutrient solution	1.25	5.50	5.50	2.00	17.50		1.50	1.25			40.00		5.00	35.00	0.75	0.50	2.18
Correction according growth stage																	
Manual correction																	
Result at temporary EC 2.18	1.25	5.50	5.50	2.00	17.50		1.50	1.25			40.00		5.00	35.00	0.75	0.50	2.18
Deviation																	
Desired recipe at EC 2.18	1.25	5.50	5.50	2.00	17.50		1.50	1.25			40.00		5.00	35.00	0.75	0.50	2.18
Input of raw water	-0.04	-0.07	-0.17	-0.27	-0.26		-0.14	-0.01	0.64								-0.11
Desired fertiliser solution	1.21	5.22	5.13	1.66	16.77		1.32	1.25	0.64		40.00		5.00	35.00	0.75	0.50	2.07
Result of fertiliser mix	1.50	5.39	5.56	1.45	16.52		1.53	1.19			40.00	6.67	2.82	17.08	0.71	0.29	2.08
Deviation	23%	3%	8%	-13%	-2%		16%	-4%					-44%	-51%	-6%	-41%	

CHECK Final result

Tank size: 1000 litre. Concentration: 100 x for: 100000 litre final plant solution.

TANK A		TANK B	
Calcinit	120 kg	Krista MgS	22.4 kg
		Kristalon Scarlet 7,5+12+36+	42.4 kg
		Kristalon Red 12+12+36+1	28.1 kg
Fe EDDHMA 6%	2335.8 g		

All specifications of the formulas are in code form.

Acid in Tank A + B
No acid

Acid harms chelates
If dripwater pH > 6: high risk of clogging.

Ratio to N = 1 mmol/l	N total	P / N	K / N	Mg / N	Ca / N	Ca / K
Desired ratio	18 mmol/l	0.07	0.29	0.09	0.29	0.98
Result in solution	18 mmol/l	0.07	0.30	0.08	0.31	1.03

(Greenhouse) soil fertigation	N standard	Correction	drip +25%	N total	EC setting (mS/cm)
N dose in mmol/l					

total input of raw water	Macro nutrients concentration in mmol/l										Micro nutrients concentration in µmol/l						
100% raw water	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	NO_3^-	Cl-	S	P	HCO_3^-	Urea	Fe	Mn	Zn	B	Cu	Mo	EC in mS/cm
	0.04	0.07	0.17	0.27	1.52	0.26	1.70	0.14	0.01	0.64								0.24
Total nutrient solution	1.53	5.46	5.72	1.72	1.52	16.78	1.70	1.07	1.19	0.64		40.00	6.67	2.82	17.08	0.71	0.29	2.28

The optimal EC depends of daily weather, crop, EC growth medium, etc.

IMPORTANT:
Check the pH and EC of the nutrient solution and root environment several times per week.

Agrico Qatar Cucumber Coco peat start BN

Disclaimer The information herein contained is to the best of Yara knowledge and belief accurate. The conditions of your use and application of the suggested formulations and recommendations, are beyond our control. The recommendations are intended as a general guide and must be adapted to suit local conditions. No warranty is made as to the accuracy of any data or statements contained herein. Yara specifically disclaims any responsibility or liability relating to the use of the suggested formulations and recommendations and shall not in any event, be liable for any special, incidental or consequential damages arising from such use.

The mother solution was prepared by diluting 120 kg of Calcinit and 2335 g of Iron chelates in tank A and 22.4 kg of Kristal MgS, 42.4 kg of Kristalon Scarlet (7.5+12+36) and 28.1 kg of Kristalon Red in Tank B. To apply nutrients to the plants the nutrients get diluted with water in proportion 100x in the irrigation machine to achieve electrical conductivity (EC) of 2.28 mS/cm of the final drip water which is applied to the plants.

The irrigation regime starts with 6 irrigation cycles 4 minutes each. As capacity of the drippers is 3l/hour then the total amount of water per plant per day is 1.2 l/ day/plant for the first month. The irrigation regime reaches 10 cycles of 4 minutes each per plant over the growth of the plant.

After one month of vegetative growth the new recipe to promote productive growth was introduced. This recipe was maintained till the end of harvest for about 2.5 months.

Table 18: Cucumber fertigation recipe, Productive growth stage

General Fertigation Advice
Adjust recommendation to suit local conditions.

This advice is valid till: 3/21/2019
After this date take a sample of the root enviroment and adjust the recommendation.

Crop : Cucumber. Coco peat. Standard.
Name : Agrico Qatar
Remark :
Date: 3/7/2019

Growth medium: Coco peat	Macro nutrients concentration in mmol/l										Micro nutrients concentration in µmol/l						
	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	NO_3^-	Cl^-	SO_4^{2-}	$H_2PO_4^-$	H_3O^+	Urea	Fe	Mn	Zn	B	Cu	Mo	EC mS/cm
Standard nutrient solution	1.25	8.00	5.00	1.50	18.00		1.50	1.25			30.00	10.00	5.00	25.00	0.75	0.50	2.23
Correction according growth stage																	
Manual correction																	
Result at temperary EC 2.23	1.25	8.00	5.00	1.50	18.00		1.50	1.25			30.00	10.00	5.00	25.00	0.75	0.50	2.23
Deviation																	
Desired recipe at EC 2.23	1.25	8.00	5.00	1.50	18.00		1.50	1.25			30.00	10.00	5.00	25.00	0.75	0.50	2.23
Input of raw water	-0.00	-0.21	-0.61	-0.42	-0.12		-0.89	-0.00	0.70								-0.11
Desired fertiliser solution	1.25	7.43	4.19	1.03	17.37		0.59	1.25	0.70		30.00	10.00	5.00	25.00	0.75	0.50	1.98
Result of fertiliser mix	1.69	7.57	4.85	0.78	16.97		0.85	1.67			30.00	8.89	3.93	23.77	1.12	0.41	2.04
Deviation	35%	2%	16%	-26%	-2%		44%	34%				-11%	-21%	-5%	50%	-17%	

CHECK Final result

Tank size: 1000 litre. Concentration: 100 x for: 100000 litre final plant solution.

TANK A		TANK B	
Calcinit	104.8 kg	Krista MgS	2.7 kg
		Kristalon Scarlet 7.5+12+36+	46 kg
		Kristalon Red 12+12+36+1	53.1 kg
Fe EDDHMA 6%	1022.3 g		

All specifications of the formulas are in oxide form.

Fe-DTPA/ED

Acid in Tank A + B
No acid

Acid harms chelates
If dripwater pH > 6: high risk of clogging.

Ratio to N = 1 mmol/l	N total	P / N	K / N	Mg / N	Ca / N	Ca / K
Desired ratio	18.6 mmol/l	0.07	0.40	0.06	0.22	0.56
Result in solution	18.7 mmol/l	0.09	0.41	0.04	0.26	0.64

(Greenhouse) soil fertigation	N standard	Correction	drip +25%	N total	EC setting [mS/cm]
N dose in mmol/l					

total input of raw water	Macro nutrients concentration in mmol/l										Micro nutrients concentration in µmol/l						EC in mS/cm
100% raw water	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Na^+	NO_3^-	Cl-	S	P	HCO_3^-	Urea	Fe	Mn	Zn	B	Cu	Mo
	0.00	0.21	0.61	0.42	5.00	0.12		0.89	0.00	0.70							0.40
Total nutrient solution	1.69	7.79	5.47	1.18	5.00	17.10		1.74	1.67	0.70		30.00	8.89	3.93	23.77	1.12	0.41	2.29

The optimal EC depends of daily weather, crop, EC growth medium, etc.

IMPORTANT:
Check the pH and EC of the nutrient solution and root enviroment several times per week

Agrico Qatar Cucumber Coco peat Standard

Disclaimer The information herein contained is to the best of Yara knowledge and belief accurate. The conditions of your use and application of the suggested formulations and recommendations, are beyond our control. The recommendations are intended as a general guide and must be adapted to suit local conditions. No warranty is made as to the accuracy of any data or statements contained herein. Yara specifically disclaims any responsibility or liability relating to the use of the suggested formulations and recommendations and shall not in any event, be liable for any special, incidental or consequential damages arising from such use.

Daily monitoring of electrical conductivity (EC) and Ph of fresh water, drip water and drain water is required to maintain the most optimum nutrient regime and to avoid salinity stress to the plants. Maintaining Ph level within the range of 5-7 is necessary to ensure that the plants absorb the most optimal amount of nutrients from the solution and the nutrients don't interact in the solution and there is no precipitation and clogging.

When deciding on number of irrigation cycles the general recommendation is to provide irrigation at least 4 times per day between sunrise and sunset. The duration of irrigation cycles determines the amount of water applied. The amount of water applied has to depend on the amount of drainage from the grow bag. In coco peat bags the target drainage amount after each irrigation cycle should be around 30%. However the first two irrigation cycles give almost no drainage as the grow bags are dry after the night when no irrigation is given.

In the trial station the following fertigation regime was maintained except for the days when the weather conditions were exceptional such as rain, high wind and extremely low humidity, low radiation.

Table 19: Fertigation schedule

Recipe	Days	Number of irrigation cycles	Minutes per cycle	Amount of water per cycle, l/m2	Total water applied daily, l/m2
Vegetative growth	First 20 days after transplantation	4	4	0.4	1.6

Productive growth	Till the end of cycle	7	6	0.6	4.2

4.3. Pest control system

See Chapter 3.6 on Pest control, products and diseases treated for tomato cultivation

5. Financial feasibility

While considering the costs of production at the trial and demonstration Center it is necessary to take into account the relatively small scale of the facilities which inflated the capital cost per square meter and therefore affected the depreciation charges.

The plant density in all Sections of the trial and demonstration Center was the same, 3 plants/m2. The amount of fertilizer solution applied was the same per one square meter in all sections. Therefore th cost of fertilizers are allocated by Section proportionate to the area of each Section. The same approach was applied for cost of Pesticides. Cost of water was determined by the actual use of water in section. In Section 1-6 water was used for irrigation and cooling. In Section 7 water was used only for irrigation. The energy cost is mostly comprised of energy used for climate in evaporative cooling system and was not allocated to Section 7.

With the yields achieved in each section and taking into account the

Table 20: Productivity and the cost of production by Section

	Units	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7
Area	m2	585	630	315	315	315	315	1,260
Production	kg	19,548	18,148	6,606	7,270	7,226	7,290	15,649
Yield	kg/m2	33.42	28.81	20.97	23.08	18.57	18.47	12.42
Energy	QAR/kg	0.07	0.08	0.12	0.11	0.08	0.08	0.00
Water	QAR/kg	0.04	0.04	0.06	0.05	0.05	0.05	0.06
Fertilizers	QAR/kg	0.35	0.41	0.59	0.53	0.40	0.41	0.56
Pesticides	QAR/kg	0.18	0.20	0.29	0.27	0.20	0.20	0.28
Packing materials	QAR/kg	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Consumables	QAR/kg	0.08	0.10	0.13	0.12	0.15	0.15	0.23
Labour cost	QAR/kg	1.04	1.21	1.66	1.51	1.16	1.16	1.73
Depreciation	QAR/kg	1.87	1.85	1.08	0.98	1.22	1.23	1.56
Total cost	**QAR/kg**	**4.20**	**4.47**	**4.51**	**4.15**	**3.83**	**3.85**	**4.99**

Although the total production in Section 3-4 is higher than in Section 5-6 the cost per kilogram of produce is Section 3-4 is higher. The reason of higher cost per kg of produce is that in Section 3-4 the cultivation of cucumbers was conducted throughout the whole season for 13 months while the cultivation in Section 5-6 for tomatoes was only for 8 months.

6. Results of the trials

The production statistics was collected for each section in the Trial and Demonstration Center for all varieties consolidated.

Table 21: Achieved productivity of tomatoes for 12 months of cultivation

Section		Section 1	Section 2	Section 5	Section 6	Section 7
Area	sqm	586	630	315	315	1260
Transplantation date 1		11/12/2018	11/12/2018	11/12/2018	11/12/2018	11/12/2018
End of Harvest		15/07/2019	15/07/2019	30/06/2019	30/06/2019	03/06/2019
Transplantation date 2		8/09/2019	8/09/2019	N/A	N/A	8/10/2019
Achieved yield	kg/sqm	33.2	29	18.6	18.5	12.5
Total harvest	**kg**	**19,450**	**18,300**	**5,851**	**5,818**	**15,691**

Since the transplantation date was relatively late in the growing season due to the late launch of the Center and the end of harvest date was determined by the outside weather conditions the production period in each Section was shorter than the potential production period achievable in Qatar. With earlier transplantation and start of harvest dates the total harvest amount in each Section can be improved by 30-50% proportionate to the number of production days.

Table 22: Production period and total harvest, actual and potential

Section		Section 1	Section 2	Section 5	Section 6	Section 7
Transplantation date		11/12/2018	11/12/2018	11/12/2018	11/12/2018	11/12/2018
Start of Harvest		26/02/2019	26/02/2019	07/03/2019	03/03/2019	13/03/2019
Potential Transplantation date		01/10/2018	01/10/2018	01/10/2018	01/10/2018	01/10/2018
Potential Start of Harvest		15/12/2018	15/12/2018	25/12/2018	25/12/2018	01/01/2019
End of Harvest		15/07/2019	15/07/2019	30/06/2019	30/06/2019	03/06/2019
Actual production period	days	139	139	115	119	82
Potential production period	days	212	212	187	187	153
Additional days in production	%	53%	53%	63%	57%	87%
Correction coefficient	%	90%	90%	90%	90%	90%
Total achieved harvest from first cultivation	kg	28.42	25.5	18.57	18.47	12.45
Potential harvest	**kg**	**39.01**	**35.00**	**27.18**	**26.12**	**20.91**

As it was mentioned earlier cucumbers were cultivated in three cultivation cycles each lasting 3.5 months.

Table 23: Achieved productivity of cucumbers for 12 months of cultivation

Section		Section 3	Section 4	Section 3	Section 4	Section 3	Section 4
Area	sqm	315	315	315	315	315	315
Transplantation date		23/12/10	23/12/10	02/05/19	02/05/19	13/08/19	13/08/19
End of Harvest		23/04/19	23/04/19	26/07/19	26/07/19	09/11/19	09/11/19
Achieved yield	kg/sq m	11.2	11.5	6.4	7.4	4.4	4.7
Total harvest	**kg**	3533	3595	2007	2336	**1377**	**1473**

7. Appendixes

7.1. Coco peat grow bags leaching and buffering protocol (ref: HF003)

Introduction:

1- Leaching: Coconut Peat/coir is naturally high in salts level especially if it was originated from coconut trees grown near the sea, these salts are relatively soluble and are not totally bound by the coir so they can be easily leached. It is necessary to make sure to leach the majority of salts before putting the seedlings in the growbags.

2- Buffering: The cation exchange sites of the Coconut Peat/coir are loaded with potassium and sodium ions, buffering is essential to exchange some of these ions with Calcium, furthermore The Coconut Peat/coir are low in calcium, they will therefore fix the calcium in the first input and create deficiencies at the plant for fertilization if calcium saturation is not done before planting.

Step 1: Prepare the growbags

- Make sure the substrate is well cantered in the plastic envelope to facilitate the expansion of product at inflation, furthermore make sure the drainage slits are free from any obstruction.
- Be careful to respect a minimum spacing of 10 cm between each bag in a row. This way the slab can reach its final wetted length without being compressed by the surrounding slabs which could cause uneven inflation.
- **Safety Precautions:** Use PPE and hand gloves.

Step 2: Day1&2 initial wetting of the grow bags

- Place the drippers inside the grow bags.
- Day1: As long as it takes give 5 minutes of water than 30 minutes stop until you see that the bags are fully wetted.
- It is important to let the substrate incorporate the water before re-watering to prevent the structure from being damaged. In the case of over-watering, the thin fibres would accumulate in the Lower-part of the substrate which would tend to lose its porosity. We must therefore avoid creating a balloon of water in the sides of the bags.
- Day2: Make sure all the bags are inflated and wetted if not continue the irrigation cycles 5 Min On /30 Min Off until all slabs are wetted.
- A well inflated slab will have “sharp” edges and be square. There will be no more free space in the bag.
- **Safety Precautions:** Use PPE and hand gloves.

Step 3: Day 3: Prepare the YaraLiva Calcinit stock solution

- In the tank A in the fertigation room, dilute 75 Kg of YaraLiva Calcinit in the 1000 liters Tank.
- Set the fertigation for salinity of 2.5 mS/cm this is approximately equivalent to 2 g of YaraLiva Calcinit in 1 liter of water.
- Make sure that every bag receives more than half if its volume of YaraLiva Calcinit solution at 2.5 mS/cm

- **Safety Precautions:** Use PPE and hand gloves. Ask help when carrying YaraLiva Calcinit bags, avoid dropping chemicals on the floor, and if spill happened, clean the area immediately.

Step 4: Day3&4: Irrigate with Buffer Solution

- The water volumes per irrigation cycle should be around 250 ml / emitter at intervals of 30 Minutes, keep the system running until the required quantity of YaraLiva Calcinit solution has been delivered.
- Around the end of the leaching cycle, collect some of the drain water and test it for EC, Ideally a salinity of 3 to 3.5 mS/cm is good enough.
- **Safety Precautions**: Use PPE and hand gloves.

7.2. Tomato seeds germination protocol (ref. HF002)

Step 1: Sterilisation of 300 Cells Seeds trays

- Start by sterilizing the seeds trays by dipping in a 10 percent bleach solution (1 part bleach added to 9 parts water)
- **Safety Precautions:** Use PPE and hand gloves, avoid bleach solution splashing into skin and eyes

Step 2: Prepare seeds germinating mix

- The seeds trays to be filled with 100% high quality low EC Coco Peat.
- Moist first the Coco Peat and manually break the big lumps until it is loose.
- Make sure mixing is done in an uncontaminated area or an area washed with 10% bleach solution.
- **Safety Precautions:** Use PPE especially gloves, mask and goggles.

Step 3: Fill the trays with germination mix.

- Fill the trays by pressing the soil into it, then remove the excess soil from the surface of the tray.
- Make sure not to cause the collapse of the tray cells walls by pressing too much.
- Make sure not to pile too many filled trays on top of each other in order not to cause uneven compaction.
- Make sure filling of trays is done on an uncontaminated surface washed by a 10% bleach solution.
- Water the trays after filling to make water compaction, add more medium to the trays if the level of the medium has collapsed due to compaction.
- **Safety Precautions**: use a raised working station to avoid stressing too much on back, use PPE and avoid letting the mix solution sip into clothes and shoes.

Step 4: Plant the seeds

- Seeding to be done manually. Place the seeds in the centres of the trays holes, then with a disinfected wood stick, pen shaped, push the seed in the hole to 0.5 to 1 cm deep, make sure to keep the seeds cantered, not too deep and not too shallow.
- Cover the hole by pushing enough of the wet germination mix to fill the gap over the seeds or by sieving some Coco peat over the tray

- **Safety Precautions:** use a raised working station to avoid stressing too much on back, use PPE and avoid letting the mix solution sip into clothes and shoes.

Step 5: Seeds germination in the acclimatized growing room

- Transfer the trays to the acclimatized and dark growing room.
- Keep the trays a couple of days in the germination room at 80% Relative Humidity and 25 degrees Celsius
- **Safety Precautions**: Use PPE.

Step 6: Transfer the trays from the germination room to the Nursery

- Transfer the trays to the Nursery and place them on a clean floor or raised beds and keep the air temperature at 20 degrees Celsius.
- If possible Maintaining light air movement through the seedling canopy. This will keep the seedlings dry and reduce the possibility of fungus diseases.
- The growth medium should be watered as needed to keep it moist, avoiding overwatering that can slow growth or lead to root disease. When watering use a standard nutrient solution for tomatoes with EC around 2ms/cm.
- **Safety precautions:** Use PPE, gloves and mask when using fungicide, After mixing the fungicide solution return the bottle to the safe store and make sure to rinse all used equipment, use impermeable plastic overall when applying fungicide, use certified chemical mask when applying fungicide, wash hand and face thoroughly after finishing the application.

Step 7: Daily watering:

- Keep trays in the Nursery for 10 days watering lightly using a shower head with thin orifices.
- Inspect the trays daily and make sure no infection is present, look for rodent attack and make sure proper rodent control is in place.
- **Safety precautions:** avoid wetting cloth while applying water manually, use proper PPE and avoid splashing water into electrical boards.

Step 9: Transplanting the seeds to the Coco Peat cubes (10cmx10cm)

- 10 to 12 days after seeding and when ready, remove the seedlings from the 300 cells trays and plant them in the 10cm x10cm Coco Peat cubes.
- Operate carefully as to not damage the seedlings.
- Plant 2 seedlings in every cube.
- After transplanting water the cubes gently with a nutrient solution when needed of EC 3.5 ms/cm.
- **Safety precautions:** Use PPE, gloves and mask when using fungicide, After mixing the fungicide solution return the bottle to the safe store and make sure to rinse all used equipment, use impermeable plastic overall when applying fungicide, use certified chemical mask when applying fungicide, wash hand and face thoroughly after finishing the application and discard the plastic coverall in an adequate chemical waste.

Step 10: Grow the seedlings inside the cubes until plants and site is ready for transplanting

- Grow the seedlings inside the cubes for 20 to 30 days until plants and site is ready for transplanting.
- **Safety precautions:** Use PPE

Step 11: Hardening the seedlings prior to transplanting

- 10 days prior to the transplanting date start decreasing the watering of the seedlings and reduce the greenhouse temperature to prepare the plants for plantation, make sure the water stress is adequate and not excessive and gradual.
- The last 3 days of hardening process stop adding any fertilisers to the irrigation water.
- **Safety precautions:** Use PPE