MELiSSA

TECHNICAL NOTE 96.11

UNIVERSITY of GUELPH

UAB
Universitat Autònoma de Barcelona

CESRF

SHERPA ENGINEERING

SHERPA ENGINEERING
269-287, rue de la Garenne 92024 Nanterre Cedex
Tel. +33 1.47.82.08.23 - Fax +33 1.47.82.00.96
SA au capital de 412.400 € - APE : 742 C- SIRET : 413 367 228 00017

TECHNICAL NOTE 96.11

Functional Testing with Schneider Controller – As-run procedures, Test results and final Test report

Prepared by/Préparé par	Tikhomirova, N., Fossen, A., Gerbi, O. and Peiro, E.
Reference/Réference	MELiSSA Pilot Plant Frame Contract 19445/05/NL/CP
Issue/Edition	0
Revision/Révision	0
Date of issue/Date d'édition	19 April 2010
Status/Statut	Final

APPROVAL

Title *Titre*	**Functional Testing with Schneider Controller – As-run procedures, Test results and final Test report**	Issue *Edition*	1	Revision *Révision*	0

Prepared by *Auteur*	Tikhomirova, N., Fossen, A., Gerbi, O. and Peiro, E.	Date *Date*	19/04/10
Checked by *Verifié par*	Peiro, E. and Fossen, A.	Date *Date*	12/05/10
Approved by *Approuvé par*	F.Gòdia	Date *Date*	12/05/10
Approved by customer *Approuvé par le client*	B. Lamaze	Date *Date*	11/10/11

CHANGE LOG

Issue/*Edition*	Revision/*Révision*	Status/*Statut*	Date/*Date*
0	0	Final	19/04/10

Distribution List

Name/*Nom*	Company/*Société*	Quantity/*Quantité*
Brigitte LAMAZE	ESA	2 hardcopies + electronic version

TABLE OF CONTENTS

1.Introduction

1.1. Purpose and Structure of Test Report

The information contained in this technical note is presenting the results of the tests carried out to ensure that the HPC1 prototype designed and constructed by the University of Guelph and Angstrom Engineering, and equipped with the Schneider control system programmed by SHERPA, adheres to the specifications of ESA, as defined in Annex to Appendix 1 of RFQ 3-11515.

UoG has tested the HPC1 chamber in the MPP (MELiSSA Pilot Plant) to demonstrate the performance and adherence to the environmental control specifications (TN96.5).
The controller tested in a first phase was the Argus Controller, considered to be a black box for the final user since the Argus company does not provide their control parameters neither their calibration procedures that they consider proprietary.
As the Control System (CS) was replaced by Schneider Hardware with Sherpa's control subroutines, new control loop tests had to be performed to demonstrate that the new system fits to the requirements.

This test report consists of three main parts. First, the series of Functional Tests performed to demonstrate the functionality of all chamber parts under the control of the Schneider PLC. Secondly, the formal control tests aimed at demonstrating Schneider PLC controlled chamber adherence to the environment control requirements listed in Annex to Appendix 1 of RFQ 3-11515. Finally the lettuce batch culture test conducted under static conditions in order to test subsystem performance under full operational conditions. The batch culture of lettuce with a Schneider Controller did not constitute a full crop cycle.

1.2. General Procedures for Test Results Data Acquisition

The functional tests outlined in Section 2 relied on either a visual inspection or confirmation of signal transfer to/from the Schneider controller. Operational tests relied on data logs recorded by the Schneider controller over the period of the test.

1.3. General Control System Test Procedures

The purpose of the control system tests outlined in Section 2 below is to demonstrate chamber performance and adherence to the environmental control specifications. As part of their sub-contract, Sherpa tuned control procedures, particularly in the case of thermal and VPD control in-house.

1.4. Recall of the conditions of Acceptance

In the case of functional tests, the requirements for acceptance of hardware are defined in the acceptance criteria of the individual test procedure, unless otherwise defined below. Acceptance of control tests is based on the technical specifications for environmental control as defined by ESA. The relevant section from the contract RFQ is reproduced below. The control test plan (sometimes referred to as the profile tests) are designed to demonstrate the functioning of the various control loops in maintaining the environmental/biological requirements defined in the table below.

Also, during the functional, operational (profile) and crop tests, the chamber shall be demonstrated to adhere to all sections of Annex to Appendix 1 of RFQ 3-11515. The requirements defined in the Annex to Appendix 1 of the RFQ are qualitative and no numerical bounds were defined.

Item	**Requirement**
Illumination light levels	0 – 800 µE PAR selectable in four discrete levels (no lamps, 3 lamps, 6 lamps, 9 lamps)
Illumination night levels	0 – 10 µE PAR
Day/night cycle	Any combination of 1 day and 1 night period within a 24 hour span
Air Temperature	Selectable within 15 – 30 °C
Temperature Accuracy	Demand +/- 0.5 °C
Internal Air (refreshment) circulation rate	Not less than 1 crop volume per minute
Air Velocity	From 0.1-0.8 m/s
Water Supply in the Roots	3 to 5 litres per minute average over all trays – equivalent to approximately 200mL/min/tray
Nutrient Supply	Hydroponics (NFT) cultivation with EC demands of 0 – 3 mS/cm pH: 5.8 +/- 0.5 EC: 1.9 mS/cm +/- 0.05 mS/cm Dissolved O_2: 80 – 100% of saturation (not analyzed ,not controllable)
Pressure	Ambient (typically 101 kPa +/- 2 kPa per hour)
Atmospheric Composition	Humidity: 50 – 85% (no accuracy specified) O_2 - 20% +/- 1% (ambient levels - not controlled) CO_2 - 300 – 2000 ppm (no accuracy for control specified) N_2 - Balance to 100% (not measured)

2. Functional, Control and Operational Tests Program as conducted for HPC1

Test	Procedure /Procedure number	Date	Duration (days)	Status (P/F)
Functional Tests				
1. Exterior Airlock Doors (Not tested as it was tested before (see TN96.5) and the change in the control system is not relevant for this particular functionality.	**MPP-HPC1–Exterior_Airlock_Door- FT** 1. Demonstration of procedures/test for opening/closing the exterior air lock doors and tray mounting/dismount. 2. Functional demonstration of the door open/closed switch/LED indicator circuit **Parts Tested (P&ID Reference):** 1. ZS_4100_01, ZS_4100_02, ZI_4100_01 2. ZS_4101_01, ZS_4101_02, ZI_4101_01	NA*	NA*	NA*
2. Interior Airlock Doors (Not tested as it was tested before (see TN96.5) and the change in the control system is not relevant for this particular functionality.	**MPP-HPC1 – Interior_Airlock_Door – FT** Demonstration of procedures/test for opening/closing the interior air lock door and tray movement in harvest and planting using glove access	NA*	NA*	NA*
3. Airlock Purge	**MPP-HPC1 – Airlock_Purge – FT** **Sequence:** Testing of air lock injection and vent solenoids **Parts Tested (P&ID Reference):** 1. RV_4100_01, SV_4102_01, SV_4102_02, PT_4102_01, PS_4102_01, HV_4102_01 2. RV_4101_01, SV_4103_01, SV_4103_02, PT_4103_01, PS_4103_01, HV_4103_01	4/02/2010 This test was performed later than the others due to software and technical reasons	0.5	Failed
4. Lighting	**MPP-HPC1 – Lighting – FT** **Sequence:** 1. Testing of the lamp loft cooling fans	22/07/09	0.05	Passed

	2. Testing of the lamp loft temperature sensors 3. Testing of the lamp loft air flow indicator 4. Testing of the lamp string relays and high-powered contactors to activate the lamps **Parts Tested (P&ID Reference):** 1. TT_4105_01, TT_4105_02, TT_4105_03 (lamp loft temperature transducers) 2. FAN_4105_01, FAN_4105_02, FAN_4105_03 (lamp loft cooling fans) 3. FSL_4105_01, FSL_4105_02, FSL_4105_03 (lamp loft air flow sensors) 4. RT_4104_01, RT_4104_02, RT_4104_03 (PAR sensors) 5. IY_4104_01, IY_4104_02, IY_4104_03 (lamp string relays and contactors) 6. LHPS_4104_01 through _06 (HPS Lamps) 7. LMH_4104_01 through _03 (MH Lamps)			
5. Main Centrifugal Blower and VFD Motor	**MPP-HPC1 – Blower_Assembly – FT** **Sequence:** 1. Visual inspection of the pulley assembly, support and rotary feed-through shaft 2. Testing of the air circulation fan 3. Testing of the air velocity sensor **Parts Tested (P&ID Reference):** 1. BLWR_4111_01 (Air Circulation Fan) 2. MVFD_4111_01 (Air Circulation Motor) 3. FT_4111_01 (Air Velocity Sensor)	22/07/09	0.1	Passed
6. Gas Analysis	**MPP-HPC1 – Gas_Analysis – FT** **Sequence:** 1. Demonstration of IRGA functioning 2. Demonstration of O_2 analyzer functioning 3. Demonstration of the factory calibrated mass flow controller (with set-point) 4. Test of CO_2 injection line solenoid	23/07/09	0.3	Passed

	Parts Tested (P&ID Reference): 1. AT_4113_01 (CO_2 Analyzer/IRGA) 2. AT_4113_02 (O_2 Sensor) 3. FC_4113_01 (Mass Flow Controller for CO_2) 4. SV_4113_01 (CO_2 injection line Solenoid)			
7. Integrity leakage Test	**MPP-HPC1 – Leakage – FT** Performance of passive CO_2 decay test with running air circulation fan to determine operational leakage rate	31/07/09-2/08/09	2	Passed
8. EC System	**MPP-HPC1 –EC – FT** **Sequence:** 1. Integrity of Stock A and B tanks 2. Stock tank A and B injection solenoids 3. Stock tank A and B low level switches 4. Stock A and B manual valves 5. Testing of EC sensor **Parts Tested (P&ID Reference):** 1. VSSL_4108_01, VSSL_4108_02 (Stock Tanks A and B) 2. SV_4108_01, SV_4108_02 (Stock A and B injection valves) 3. LSL_4108_01, LSL_4108_02 (Stock A and B tank low level switches) 4. HV_4108_01, HV_4108_01 (Stock A and B Injection Manual Override Valves 5. AT_4108_01 (EC Sensor)	15/07/09	0.05	Passed
9. pH	**MPP-HPC1 – pH – FT** **Sequence:** 1. Integrity of Acid and Base tanks 2. Testing of Acid and Base Tank injection solenoids 3. Testing of Acid and Base Tank low level switches 4. Demonstration of Acid and Base Tank manual valves 5. Testing of pH sensor **Parts Tested (P&ID Reference):** 1. VSSL_4107_01, VSSL_4107_02 (Acid and Base Tanks) 2. SV_4107_01, SV_4107_02 (Acid and Base injection valves)	9/07/09	0.05	Passed

	3. LSL_4107_01, LSL_4107_02 (Acid and Base tank low level switches) 4. HV_4107_01, HV_4107_01 (Acid and Base Injection Manual Override Valves) 5. AT_4107_01 (pH Sensor)			
10. Irrigation System	**MPP-HPC1 – Irrigation – FT** **Sequence:** 1. Integrity of nutrient reservoir and plumbing (leakage) 2. Demonstration of main irrigation pump 3. Testing of irrigation flow sensor 4. Demonstration of manual valves positioned on the by-pass and main irrigation lines 5. Demonstration of irrigation flow balancing along the internal distribution manifold 6. Testing of nutrient tank Hi/Low switches **Parts Tested (P&ID Reference):** 1. GP_4106_01 (Main Irrigation Pump) 2. FT_4106_01 (Irrigation Flow Sensor) 3. HV_4106_01 (Manual shutoff to chamber) 4. Irrigation manifold in chamber 5. HV_4106_02 (Irrigation Pump Inlet Manual Override) 6. HV_4106_03 (Irrigation Drain Manual Override) 7. HV_4106_04 and HV_4106_05 (Irrigation By-pass Isolation Valves) 8. HV_4106_05, HV_4106_06, HV_4106_7, HV_4106_8 (Manifold Balancing Ball Valves) 9. VSSL_4106 (Nutrient Reservoir)	12/11/09	0.1	Passed
11. Temperature, Humidity and condensate collection	**MPP-HPC1 – Temp_Humidity – FT** **Sequence:** 1. Testing of growing volume temperature sensors 2. Testing of growing volume integrated humidity/temperature sensors 3. Integrity and functionality of hot water coil 4. Integrity and functionality of chilled water coil	19/11/09	0.1	Passed

	5. Functionality of chilled and hot water valve 6. Functionality of temperature sensors of water service lines and coil surface temperature 7. Integrity of condensate tank and fittings 8. Testing of passive condensate drain from coil drip tray 9. Testing of condensate tank high and low level switches 10. Testing of condensate pump **Parts Tested (P&ID Reference):** 1. TT 4112_04 - _012 (Growing volume temperature sensors) 2. AT 4112_01 - *03* and TT 4112_01 - _03 (growing volume humidity and temperature sensors) 3. S3CV_4112_01 and S3CV_4112_02 (water service line control valves) 4. TT_4112_13 - _18 (water service line entry and exit temperature sensors, coil surface temperature sensors) 5. VSSL_4110_01 (Condensate Tank) 6. LSL_4110_01, LSH_4110_02 (Condensate tank hi and low level switches) 7. GP_4110_01 (Condensate pump and relay)			
Control/Profile Tests				
Exterior Air Lock Door Control Loop 4100 and 4101	**MPP-HPC1-Exterior_Airlock_Door - CT** 1. Confirmation of controller reading of ZS_4100_01, ZS_4100_02, ZS_4101_01 and ZS_4101_02	NA*	NA*	NA*
Airlock Purge Control Loop 4102 and 4103	**MPP-HPC1 –Airlock_Purge – CT** 1. Confirmation of pressure sensor log PT_4102_01, PT_4103_01 2. Confirmation of reading pressure switch PS_4102_01 and PS_4103_01	22/07/09	0.05	Passed
Lighting Intensity and Loft Temperature Control Loop 4104 and 4105	**MPP-HPC1 – Lighting – CT** 1. Sequential activation of lamp strings (LPHS_4104_01 through LHPS_4104_06 and LMH_4104_01 through LMH_4104_03 and activation of contactors IY_4104_01 through IY_4104_03) 2. Confirmation of controller log of PAR sensors (RT_4104_01 through RT_4104_03)	4/08/09	0.3	Passed

	3. Confirmation of air loft fan operation (FAN_4105_01, through FAN_4105_03) by controller 4. Confirmation of FAN operation indicator (FSL_4105_01 through FSL_4104_03) 5. Confirmation of controller log of lamp loft temperatures (T_4105_01 through TT_4105_03) 6. Confirmation lamp loft temperature remains below 35 ºC during operation of one photoperiod (assuming ambient temperatures are maintained at or below 21C) 7. Induction of high air loft temperature alarm states			
Irrigation Control Loop 4106	MPP-HPC1 – Irrigation – CT 1. Confirmation of controller log of nutrient flow sensor (FT_4106_01) 2. Confirmation of nutrient flow rates greater than 0.2 L per minute	15/07/09-17/07/09	3	Passed
pH Control Loop 4107	**MPP-HPC1 –pH – CT** 1. Confirmation of pH sensor log AT_4107_01 at the controller 2. Confirmation of controller read of acid and base tank low level sensors (LSL_4107_01 and LSL_4107_02) 3. Confirmation of controller activation of acid and base injection solenoids by the controller (SV_4107_01 and SV_4107_02) 4. Induction of hi/low pH alarms	15/07/09-17/07/09	3	Passed
EC Control loop 4108	**MPP-HPC1 –EC – CT** 1. Confirmation of EC sensor log AT_4108_01 at the controller 2. Confirmation of controller read of stock A and stock B tank low level sensors (LSL_4108_01 and LSL_4108_02) 3. Confirmation of controller activation of stock injection solenoids by the controller (SV_4108_01 and SV_4108_02) 4. Induction of hi/low EC alarms	15/07/09-17/07/09	3	Passed
Condensate Collection Control Loop 4110	**MPP-HPC1 – Condensate – CT** Activation of condensate drain procedure by the controller	15/07/09-17/07/09	3	Passed
Growing Volume Temperature and Humidity Control	**MPP-HPC1 –Temperature – CT** Diurnal profile tests in temperature/humidity control (demand	15/07/09-17/07/09	3	Passed

Control Loop 4112	vs. actual). To be performed during crop test			
CO_2 compensation control Control Loop 4113	**MPP-HPC1 –CO_2 – CT** Profile tests of CO_2 control by the controller	17/07/09, 15/08/09- 17/08/09	4	Passed
Crop Test	**MPP-HPC1 – Crop– OT** 1. Crop trial with lettuce in batch culture under nominal conditions – approximately 7 days in duration 2. Collection of NCER data 3. Collection of evapo-transpiration data 4. Collection of T/RH data	21/08/09- 28/08/09, 21/08/09- 1/09/09	7-11	Passed

*- tests are not applicable

3. Air Lock Purge System Functional Testing

3.1 Procedure ID: MPP-HPC1-AIRLOCK_PURGE – FT

3.2 Introduction

The aim of this test is to demonstrate and test the operation of the air lock purge system, including the over-pressure passive relief valves, pressure transducers, pressure switches and purge in/vent solenoids of both air locks A and C.

3.3 Acronyms used in this test plan procedure

None

3.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

3.5 Data Log File Names:

Not Applicable

3.6 Parts Tested (P&ID Reference):

1. SV_4102_01_MV, SV_4102_02_MV, SV_4103_01_MV, SV_4103_02_MV
2. HV_4102_01 HV_4103_01
3. PS_4102_01, PS_4103_01
4. PT_4102_01, PT_4103_01

3.7 Acceptance/rejection criteria

General

The test is considered successful when the following conditions are met

Acceptance criteria

Proper functioning of the following parts is demonstrated, according to the conditions noted;

1. Air lock inlet and purge solenoids SV_4102_01_MV, SV_4102_02_MV, SV_4103_01_MV, SV_4103_02_MV open when charged and re-main closed when no current is applied
2. Air lock pressure switches PS_4102_01, PS_4103_01 are activated when an over pressure air stream is applied to the inlet port of each sensor

Rejection criteria

The test shall be repeated if any of the conditions outlined above are not met.

3.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior and interior air lock doors shall be closed in this test, blower on.

3.9 Safety aspects

No special safety risks have been identified for this test.

3.10 Test set-up

Ancillary Equipment Required for Test:

1. Air source
2. 1 metre of Teflon or polypropylene tubing

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint

Air Lock	Interior Air Lock Doors (A&C)	N/A	Closed	
Air Lock	Exterior Air Lock Doors (A&C)	N/A	Open	Airlock doors are open to allow connection of tubing to inlet and outlet ports of the purge system
Air Lock	Purge Inlet Solenoids (Airlock A and C)	SV_4102_01 SV_4103_01	Closed	
Air Lock	Purge Vent Solenoids (Airlock A and C)	SV_4102_02 SV_4103_02	Closed	
Air Lock	Pressure Switches (Airlock A and C)	PS_4102_0 PS_4103_01	Not Activated	
Air Lock	Pressure Transducers (Airlock A and C)	PT_4102_01 PT_4103_01	Reading ambient	Nominal sensor functioning is all that is required for this test

3.11 Test As-Run Procedure

Date: 4.02.2010 Time:			Test Engineer/operator: Olivier Gerbi (Sherpa), Christophe Bourg (Sherpa), Raul Moyano MPP Supervision: Natalia Tikhomirova		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P)/ Fail (F)
1	Connect a cylinder with calibrated air (1000 ppm CO_2) to the purge gas inlet line on the external solenoid panel				P
2	Using the Schneider control system, enable CO_2 control in auto mode	CO_2 concentration in the chamber is 1000 ppm	997.5 ppm	See deviations table 3.13	P
1	Disable CO_2 control				P
3	Open exterior door of airlock A for 1 minute			Test for airlock A was not performed due to failure of SV_4102_01_M opening from	F

				Schneider control system	
4	Close exterior door of airlock A				F
5	Using the Schneider control system, open SV_4102_01_M and inject calibrated air during 1 minute			These actions are done under control of pressure. If the pressure is higher than 1.03 bar, or if the opening door A alarm is ongoing, the air injection is stopped	F
6	Using the Schneider system, observe and record the pressure sensor PT_4102_01 reading for air lock A				F
7	Using the Schneider system, check that pressure switch PS_4102_01 is activated and SV_4102_02_M is opened				F
8	Using the Schneider control system, enable CO_2 control in auto mode	CO_2 concentration in the chamber is 1000 ppm	996 ppm	See deviations table 3.13	P
9	Disable CO_2 control				P
10	Open exterior door of airlock C for 1 minute				P
11	Using the Schneider control system, open SV_4103_01_M and inject calibrated air during 1 minute			These actions are done under control of pressure. If the pressure is higher than 1.03 bar, or if the opening door A alarm is ongoing,	P

				the air injection is stopped	
12	Using the Schneider system, observe and record the pressure sensor PT_4103_01 reading for air lock C		Value of pressure was not changed after air injection, it was about 996 mbar		P
13	Using the Schneider system, check that pressure switch PS_4103_01 is activated and SV_4103_02_M is opened			The injection of calibrated air in the air-lock does not increase the pressure in the air-lock and the condition to open the exhaust valve (Pressure switch) cannot be realized	F
14	Open exterior and interior doors of the chamber, stop the blower				P

3.12 Conclusions

The injection of calibrated air in the air-lock does not increase the pressure, neither in the air-lock nor in the chamber. However we can visually see that the bags of the chamber inflate to compensate the pressure with the exterior. The non variation of pressure is due to the interior door which is flexible and partially permeable.
The condition to open the exhaust valve (Pressure switch) cannot be realized.
Interior door closed. When opening the exterior door we can see a very small decrease of the CO_2 in the chamber. It is normal as the pressure in the chamber is equal to the exterior pressure (no pressure drop). So opening the exterior door is not dangerous for the chamber.

3.13 Deviations

Seq. Nb.	Description of the modification	Justification
2 & 8	Measured CO_2 concentration in the chamber was less than required	Deviation was in the frames of offset and did not influence

4. Lighting Sub-System Functional Testing

4.1 Procedure ID: MPP-HPC1-LIGHTING-FT

4.2 Introduction

The aim of this test is to demonstrate the proper functioning of the chamber lighting system. This includes demonstration of proper functioning of the lamp loft fans, temperature sensors, air flow indicators and the relays and contactors for illumination of the 2 HPS lamp strings and the MH lamp string. Testing of the functioning of factory calibrated PAR sensors is also performed.

4.3 Acronyms used in this test plan procedure

LHPS – High Pressure Sodium lamp
LMH – Metal Halide lamp
PAR – Photosynthetically Active Radiation

4.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

4.5 Data Log File Name:

MPP_HPC_-LIGHTING_FT.txt

4.6 Parts Tested (P&ID Reference):

1. TT_4105_01, TT_4105_02, TT_4105_03 (lamp loft temperature transducers)
2. FAN_4105_01, FAN_4105_02, FAN_4105_03 (lamp loft cooling fans)
3. FSL_4105_01, FSL_4105_02, FSL_4105_03 (lamp loft air flow sensors)

4. RT_4104_01, RT_4104_02, RT_4104_03 (PAR sensors)
5. IY_4104_01, IY_4104_02, IY_4104_03 (lamp string relays and contactors)
6. LHPS_4104_01 through _06 (HPS Lamps)
7. LMH_4104_01 through _03 (MH Lamps)

4.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely

The test is considered successful when the following conditions are met

Acceptance criteria

1. The lamps in string HPSa illuminate when activated by the controller and yield an average PAR level of not less than 300 µE at crop height (30 cm above bench) when the sensor is placed in the horizontal centre of the reflector for each lamp in string HPSa
2. The lamps in string HPSb illuminate when activated by the controller and yield an average PAR level of not less than 300 µE at crop height (30 cm above bench) when the sensor is placed in the horizontal centre of the reflector for each lamp in string HPSb
3. The lamps in string MH illuminate when activated by the controller and yield an average PAR level of not less than 140 µE at crop height (30 cm above bench) when the sensor is placed in the horizontal centre of the reflector for each lamp in string MH
4. The lamp loft fans all remain functional during periods of illumination
5. All alarms, listed in the test procedure, are activated
6. The temperature in any of the lamp loft does not exceed 40 C at any time during lamp operation under normal external temperature conditions

Rejection criteria

The test is considered to have failed under the following conditions;

1. When any of the conditions stated above are not met
2. When any of the data acquisition looks doubtful or failed completely

4.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber air lock doors shall remain open during this test (i.e. chamber not sealed) so as to allow the test engineer/operator the ability to move PAR sensors to the required positions. Air temperature with the MPP must be maintained between 19C and 21C during the entire test period.

4.9 Safety aspects

The operator shall take care when entering the chamber to take PAR measurements. The operator taking measurements should weigh less than 100 Kg.

All growing trays but three should be removed from the chamber to avoid a trip hazard when moving about the chamber interior.

The lower air flow baffles should not be in position as they will not support any operator's weight.

Care should be taken to avoid stepping on the hydroponic feed lines.

The operator entering the chamber shall be aware of the air flow return duct (hole) in the chamber floor. Care must be taken not to trip or fall in.

Because the operator will be inside the chamber, the air lock doors must remain open during this test.

4.10 Test set-up

Ancillary Equipment Required for Test:

- PAR sensors installed in chamber (RT_4104_01, RT_4104_02, RT_4104_3)
- step ladder to gain entry into the HPC
- anemometer

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Lighting System	Lamp String HPSa , including lamps: LHPS_4104_01 (HPS Lamp Aa) LHPS_4104_02 (HPS Lamp Ba) LHPS_4104_03 (HPS Lamp Ca)	IY_4104_01	Off	
	Lamp String HPSb, including lamps: LHPS_4104_04 (HPS Lamp Ab) LHPS_4104_05 (HPS Lamp Bb) LHPS_4104_06 (HPS Lamp Cb)	IY_4104_02	Off	

	Lamp String MH, including lamps: LMH_4104_01 (MH Lamp A) LMH_4104_02 (MH Lamp B) LMH_4104_03 (MH Lamp C)	IY_4104_03	Off	
	PAR Sensor A	RT_4104_01	Logging	Should initially read 0 uE
	PAR Sensor B	RT_4104_02	Logging	Should initially read 0 uE
	PAR Sensor C	RT_4104_03	Logging	Should initially read 0 uE
	Loft Fans A	FAN_4105_01 and FAN_4105_02	Off	Both fans in loft A should be off
	Loft Fans B	FAN_4105_03 and FAN_4105_04	Off	Both fans in loft B should be off
	Loft Fans C	FAN_4105_05 and FAN_4105_06	Off	Both fans in loft C should be off
	Loft Temperature Sensor (Loft T – A)	TT_4105_01	Logging	Should read ambient temperature
	Loft Temperature Sensor (Loft T – B)	TT_4105_02	Logging	Should read ambient temperature
	Loft Temperature Sensor (Loft T – C)	TT_4105_03	Logging	Should read ambient temperature
	Loft Air Flow Sensor (Flow – A)	FSL_4105_01	Logging	Should indicate no air flow in loft
	Loft Air Flow Sensor (Flow – B)	FSL_4105_02	Logging	Should indicate no air flow in loft
	Loft Air Flow Sensor (Flow – C)	FSL_4105_03	Logging	Should indicate no air flow in loft

4.11 Test As-Run Procedure

Date:22.07.2009 Time:			Test Engineer/operator: Raul Moyano MPP Supervision: Raul Moyano		
Seq.	Description	Required/	Measured/	Remarks/Calculation	Pass (P)/ Fail (F)

Nb.		Nominal	calculated		
1	Position and centre PAR Sensor A (RT_4104_01) underneath the HPS lamp reflector that is member of string HPSa in module A and fix it at a height of approximately 30 cm above growing tray height	0 uE	0.6 uE	See deviations table 4.13	P
2	Position and centre PAR sensor A (RT_4104_02) underneath the HPS lamp reflector that is member of string HPSa in module B and fix it at a height of approximately 30 cm above growing tray height	0 uE	0.15 uE	See deviations table 4.13	P
3	Position and centre PAR sensor (RT_4104_03) underneath the HPS lamp reflector that is member of string HPSa in module C and fix it at a height of approximately 30 cm above growing tray height	0 uE	00.15 uE	See deviations table 4.13	P
4	Operator confirms operation of the fans by taking readings at the outlet (back) side of the fans with a hand-held anomemeter. All fans should yield a reading of greater than 0.10 m/s	Anemometer readings from each fan > 0.10 m/s	1.5 m/s 1.9 m/s__ A 1.35 m/s 1.75 m/s B 1.6 m/s 1.8 m/s C	Average: 1.7 m/s Average: 1.55 m/s Average:1.7 m/s	P
5	In the Schneider control system, confirm air flow indicators in each lamp loft (FSL_4105_01, _02 and _03)	FSL_4105_01, _02 and _03 indicate air flow		Air flow indicator of FSL_4105_02 is off or blinking, but the fan works properly. Problem of signal that doesn't arrive to HMI	P
6	Confirm that temperature sensors in each lamp loft read ambient temperatures (TT_4105_01,	TT_4105_01, _02 and _03	TT_4105_01, _02 and		P

	_02 and _03)	read AMBIENT	_03 read AMBIENT		
7	Using the Schneider control system, activate lamp string HPSa	LHPS_4104_01, _03 and _05 are ON	LHPS_4104_01, _03 and _05 are ON		P
8	After a period of 10 minutes, confirm readings of PAR sensors A-C (RT_4104_01, _02 and _03) each read above 300 uE corresponding to illumination of lamp string HPSa	RT_4104_01, _02 and _03 read > 300 uE	RT_4104_01 – 316 uE, RT_4104_02 – 320 uE, RT_4104_03 – 327 uE		P
9	Deactivate lamp string HPSa				P
10	Confirm all air loft fans remain running				P
11	Position and centre PAR sensor (RT_4104_01) under the HPS lamp reflector that is member of string HPSb in module A	0 uE	0.6 uE	See deviations table 4.13	P
12	Position and centre PAR sensor (RT_4104_02) under the HPS lamp reflector that is member of string HPSb in module B	0 uE	0.3 uE	See deviations table 4.13	P
13	Position and centre PAR sensor (RT_4104_03) under the HPS lamp reflector that is member of string HPSb in module C	0 uE	0.15 uE	See deviations table 4.13	P
14	Activate lamp string HPSb				P
15	Confirm continued operation of all lamp loft fans				P
16	After a warm-up period of 10 minutes, confirm and record readings of PAR sensors corresponding to illumination of HPSb	RT_4104_01, _02 and _03 read > 300 uE	RT_4104_01 – 315 uE, RT_4104_02 – 313 uE, RT_4104_03 – 307 uE		P
17	Deactivate lamp string HPSb				P
18	Confirm all air loft fans remain running				P
19	Position and centre PAR sensor (RT_4104_01) underneath the MH lamp reflector that is	0 uE	0.76 uE	See deviations table 4.13	P

	member of string MH in module A				
20	Position and centre PAR sensor (RT_4104_02) underneath the MH lamp reflector that is member of string MH in module B	0 uE	0.31 uE	See deviations table 4.13	P
21	Position and centre PAR sensor (RT_4104_03) underneath the MH lamp reflector that is member of string MH in module C	0 uE	0.31 uE	See deviations table 4.13	P
22	Activate lamp string MH				P
23	Confirm continued operation of all lamp loft fans				P
24	Confirm readings of PAR sensors corresponding to illumination of MH	RT_4104_01, _02 and _03 read >140 uE	RT_4104_01 – 125 uE, RT_4104_02 – 133 uE, RT_4104_03 – 129 uE	See deviations table 4.13	P
25	Activate lamp string HPSa				P
26	Activate lamp string HPSb				P
27	Activate lamp string MH				P
28	Confirm continued operation of all lamp loft fans				P
29	Confirm log of lamp loft temperature sensors Loft-T A-C, record initial values		26.93 A 26.15 B 26.67 C		P
30	Allow lamps to run for 1 hour				P
31	To test the temperature override control; lower the temperature limits on the control system to invoke a lamp loft high temperature alarm condition. Ensure the lamps shut off.			Since operator is not able to change the set point for a lamp loft temperature alarms this operation was not done.	F

32	Confirm continued operation of lamp loft fans			Since operator is not able to change the set point for a lamp loft temperature alarms this operation was not done	F
33	Turn off lamps and let cool for 15 minutes			Since operator is not able to change the set point for a lamp loft temperature alarms this operation was not done	F
34	Reset lamp loft temperature limits and reactivate lamps			Since operator is not able to change the set point for a lamp loft temperature alarms this operation was not done	F
35	Controller instructs lamp strings (HPSa, HPSb, and MH) to operate for an extended period.			Since operator is not able to change the set point for a lamp loft temperature alarms this operation was not done	F
36	After this period confirm shut-off of all lamp strings.			Since operator is not able to change the set point for a lamp loft temperature alarms this operation was not done	F

4.12 Conclusions

The test was passed successfully after adapting the success criteria for MH lamps due to the power decrease over time. The test of the temperature override control failed as the operator is not allowed to change the set point for loft temperature (parameter fixed in the software).

4.13 Deviations

Seq.	Description of the modification	Justification

Nb.		
1 2 3 11 12 13 19 20 21	Requirements for PAR sensors readings have been changed to 0-0.9 uE	In the frames of PAR sensors' measurements deviation (offset)
24	Readings of PAR sensors for MH lamps were lower than required and acceptance criteria was thus changed to: The lamps in string MH illuminate when activated by the controller and yield an average PAR level of not less than 120 µE at crop height (30 cm above bench) when the sensor is placed in the horizontal centre of the reflector for each lamp in string MH	Initial requirement for measurement of MH lamps PAR level was taken according to the measurements made 4 months ago (March, 2009) for the test with Argus controller. But with time light intensity of the lamps decrease that is why it is impossible to have the same PAR level after 4 months of lamps operation. Decrease of PAR level was very minor and no impact on plants growth was expected.

5. Air Circulation Fan Functional Testing

5.1 Procedure ID: MPP-HPC1 – Blower_Assembly – FT

5.2 Introduction

The aim of this test is to demonstrate the proper functioning of the centrifugal blower, VFD motor, pulley and belt drive for the motor, rotary feed through shaft and by consequence, the chamber shell ducting and louvers.

The test begins with the VFD motor set to 50 Hz which will enable the main centrifugal blower to run at full speed. After equilibration and air speed measurements have been recorded by the Schneider Control system, the speed controller is reduced incrementally to show function at a range of speeds. The test concludes with a demonstration of the ramp-up and ramp-down capability in starting or shutting off of the motor of the main centrifugal blower.

5.3 Acronyms used in the test

VFD – Variable Frequency Drive (of the motor driving the main centrifugal blower)

5.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID
VFD Operation Manual
Motor Operation Manual

5.5 Data Log File Name:

MPP_HPC1__AIR_CIRCULATION_FT.txt

5.6 Parts Tested (P&ID Reference):

1. BLWR_4111_01 (Air Circulation Fan)
2. MVFD_4111_01 (Air Circulation Motor)
3. FT_4111_01 (Air Velocity Sensor)

5.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the following conditions are met

Acceptance criteria

The functional tests of the air handling sub-system components are deemed acceptable when;

- When the VFD successfully ramps from 0 Hz to 50 Hz without damage
- When the VFD successfully ramps down from 50 Hz to 0 Hz without damage
- When sufficient air flow is measured by FT_4111_01

5.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber air lock doors shall remain open during this test (i.e. chamber not sealed).

5.9 Safety aspects

When the motor and pulley are in operation under the chamber belly, the operator shall take care to get items caught in the fan belt and pulley assembly. Yellow caution tape should surround the perimeter of module C.

5.10 Test set-up

All growing trays and bottom air louvers must be in place for this test.

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Air handling unit	Main centrifugal blower		Idle	
	VFD Motor		Off	

5.11 Test As-Run Procedure

Step by step description of the operations performance

Date: 22.07.2009 Time:			Test Engineer/operator: Raul Moyano MPP Supervision: Raul Moyano		
Seq. Nb.	Description	Required / Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Visually inspect the rotary feed-through shaft and pulley system to confirm that there is no				P

	deflection in the assembly at system rest				
2	Activate the VFD and set to 50 Hz. Record air flow of the internal air velocity sensor (FT_4111_01) as indicated on the Schneider control system overview screen		26.11 m/s		P
3	Activate the VFD and set to 40 Hz. Record air flow of the internal air velocity sensor (FT_4111_01) as indicated on the Schneider control system overview screen		20.30 m/s		P
	Activate the VFD and set to 30 Hz. Record air flow of the internal air velocity sensor (FT_4111_01) as indicated on the Schneider control system overview screen		14.57 m/s		P
	Activate the VFD and set to 20 Hz. Record air flow of the internal air velocity sensor (FT_4111_01) as indicated on the Schneider control system overview screen		9.22 m/s		P
	Activate the VFD and set to 10 Hz. Record air flow of the internal air velocity sensor (FT_4111_01) as indicated on the Schneider control system overview screen		4.32 m/s		P
16	Return the VFD to 0 Hz, main centrifugal blower remains idle		0 m/s		P

5.12 Conclusions

The test was successful.

5.13 Deviations

Seq. Nb.	Description of the modification	Justification

6. Gas Analysis System Functional Testing

6.1 Procedure ID: MPP-HPC1-GAS_ANALYSIS – FT

6.2 Introduction

The aim of this test is to demonstrate and test the operation of the gas analysis system components including functioning of the IRGA for CO_2, O_2 analyzer, mass flow controller for CO_2 injection, manual injection over-ride valve and the CO_2 injection line solenoid.

6.3 Acronyms used in this test plan procedure

IRGA – InfraRed Gas Analyzer for CO_2
PO2 – Paramagnetic Analyzer for O_2

6.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

6.5 Data Log File Names:

MPP_HPC1__GAS ANALYSIS_FT.txt

6.6 Parts Tested (P&ID Reference):

1. AT_4113_01 (CO_2 Analyzer/IRGA)
2. AT_4113_02 (O_2 Sensor)
3. FC_4113_01 (Mass Flow Controller for CO_2)
4. SV_4113_01 (CO_2 injection line solenoid)
5. HV_4113_01 (CO_2 injection line manual over-ride valve)

6.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the following conditions are met:

Acceptance criteria

Proper functioning of the following parts is demonstrated, according to the conditions noted;

1. The IRGA (AT_4113_01) reads ambient CO_2 (300 – 500 ppm) concentrations prior to test
2. The IRGA (AT_4113_01) responds to automated CO_2 injection by the Schneider control system at a setpoint of 1500 ppm
3. The PO2 (AT_4113_02) reads ambient conditions prior to and during the test
4. The Mass Flow Controller for CO_2 is automatically controllable to a set point of 200 mL/min and flow of CO_2 through the MFC is confirmed
5. Proper functioning of the CO_2 injection line solenoid (SV_4113_01) is demonstrated

Rejection criteria

The test shall be repeated if the data acquisition looks doubtful or failed completely or if any of the conditions outlined in Section 2.2 are not met.

6.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior and interior air lock doors shall be closed in this test but no special environment control of the interior of the chamber is required.

6.9 Safety aspects

Carbon dioxide and nitrogen are asphyxiants. Care must be used when employing this gas in its pure form.

6.10 Test set-up

Ancillary Equipment Required for Test:

1. Pressure regulated and adjustable (0 – 120 kPa) 99.99% (or better) CO_2 gas source with to be connected to the CO_2 injection line inlet solenoid (SV_4113_01)
2. Calibrated air source (certified with levels according to anayzer manufacturer instructions) and regulator (0 – 120 kPa delivery) to be connected to the CO_2 analyzer when required for span calibration
3. Calibrated air source of 99.99 or better purity Nitrogen with a regulated supply to be connected to the CO_2 analyzer when required for zero calibration

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Gas Analysis	IRGA	AT_4113_01	Connected to HPC1 through dedicated inlet and outlet lines. Analyzer is turned on and operational	Confirm air flow through analyzer and operation of analyzer sampling pump. Analyzer sample return is back to the chamber growing volume to create a closed sampling system
Gas Analysis	PO2	AT_4113_02	Integrated with CO_2 analyzer	
Gas Analysis	Mass Flow Controller for CO2	FC_4113_01	Closed (0 L/min flow)	
Gas Analysis	CO2 injection line solenoid	SV_4113_01	Closed	
Gas Analysis	CO2 injection line manual over-Ride ball valve	HV_4113_01	Closed	No CO2 gas supplied to inlet solenoid at start of test
Air Lock	Exterior Air Lock Doors	N/A	Closed	
Air Lock	Interior Air Lock Doors	N/A	Open	
Air Circulation	Main Blower and VFD	BLWR_4111_01, MVFD_4111_01	Running at optimal speed (TBD)	

6.11 Test As-Run Procedure

<table>
<tr><td colspan="3">Date: 23.07.2009
Time:</td><td colspan="3">Test Engineer/operator: Raul Moyano
MPP Supervision: Raul Moyano</td></tr>
<tr><td>Seq. Nb.</td><td>Description</td><td>Required/ Nominal</td><td>Measured/ calculated</td><td>Remarks/Calculation</td><td>Pass (P) Fail (F)</td></tr>
</table>

1	Calibrate the IRGA/PO_2 analyzer			See anayzer operating manual for calibration instructions	P
2	The mass flow controller is set to delivery CO_2 at a rate of 200 mL/min using the Schneider Control System	FC_4113_01 is set to deliver CO_2 at 200 mL/min		See MFC operating manual for manual setting of MFC	P
3	Set the Schneider control system CO_2 demand to 1500 ppm	SV_4113_01 is OPEN	SV_4113_01 is OPEN	*Initial CO2 concentration: 403 ppm*	P
4	Open the CO_2 line delivery pressure of 110 kPa	CO_2 tank regulator delivery at 110 kPa			P
5	Open the CO_2 injection (SV_4113_01) override valve	SV_4113_01	SV_4113_01		P
6	Monitor CO_2 concentrations on the Schneider control system AND the IRGA and ensure that both are reading approximately the same value. CO_2 levels should rise within the HPC The PO_2 (AT_4113_02) should continue to read ambient concentrations	AT_4113_01 indicating rising CO_2 AT_4113_02 reading ambient O_2 (~21%)	AT_4113_01 indicating rising CO_2 AT_4113_02 reading ambient O_2 (~21%)	The Schneider controller will record CO_2 concentration	P
7	[CO_2] should reach 1500 and automated injection discontinues		1700 ppm	[CO2] levels may somewhat surpass the 1500 limit as internal mixing and analyzer lag times limit response. Without active CO2 consumption and in the absence of major leaks, [CO2] will remain high	P
8	On the Schneider control system, return the CO_2 control to 'Manual off', close the CO_2 injection override valve (SV_4113_01)				P

6.12 Conclusions

the test was successful ; the analyzer calibration certificates and calibration gases composition certificates are available in the corresponding files in the MPP

6.13 Deviations

Seq. Nb.	Description of the modification	Justification

7. Chamber Shell Integrity Leakage Test

7.1 MPP-HPC1-LEAKAGE-FT

7.2 Introduction

The aim of this test is to demonstrate the integrity of the chamber shell after assembly. CO_2 is injected into the chamber in a closed and idle configuration (all sub-systems off, main centrifugal blower excepted) to a set-point of 1500 ppm. CO_2 is allowed to passively decay through the chamber shell over a 48 hour period. The rate of leakage is calculated as the slope of a tangent to a 24 hour CO_2 curve, expressed as % Leakage of CO_2 (relative to initial value) per day.

7.3 Acronyms used in this test plan procedure

MFC – Mass Flow Controller
IRGA – Infra-Red Gas Analyzer for CO_2 (0-6000 ppm)

7.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

7.5 Data Log File Name:

MPP_HPC1__LEAKAGE_FT.txt

7.6 Parts Tested (P&ID Reference)

Chamber closure integrity

7.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the conditions outlined below are met.

Acceptance Criteria

The diffusive CO_2 leakage rate from inside the chamber against ambient total pressure and partial pressures of CO_2, calculated as the slope of a tangent to a 48 hour CO_2 concentration decay curve at the operational condition of 1000 ppm, expressed as % Leakage of CO_2 (relative to initial value) per day is less than 7% per day

Rejection Criteria

The diffusive CO_2 leakage rate from inside the chamber against ambient total pressure and partial pressures of CO_2, calculated as the slope of a tangent to a 48 hour CO_2 concentration decay curve at the operational condition of 1000 ppm, expressed as % Leakage of CO_2 (relative to initial value) per day is greater than 7% per day

7.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior air lock doors shall remain closed during this test but the interior air lock doors shall remain open.

During the test the CO_2 concentration will be increased to 1200 ppm with the main centrifugal blower running.

7.9 Safety aspects

1. The operator must not enter the chamber during the test due to high CO_2 levels
2. The exterior doors and all interface ports must remain sealed

7.10 Test set-up

Ancillary Equipment Required for Test:

1. Pressure regulated and adjustable (0 – 120 kPa) 99.99% (or better) CO_2 gas source with to be connected to the CO_2 injection line inlet solenoid (SV_4113_01)
2. Calibrated air source (certified with concentrations according to manufacturer's instructions) and regulator (0 – 120 kPa delivery) to be connected to the CO_2 analyzer when required for calibration
3. Calibrated air source of 99.99 or better purity Nitrogen with a regulated supply to be connected to the CO_2 analyzer when required for calibration

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Gas Analysis	IRGA	AT_4113_01	Connected to HPC1 through dedicated inlet and outlet lines. Analyzer	Confirm air flow through analyzer and operation of analyzer sampling pump.

			is turned on and operational	Analyzer sample return is back to the chamber growing volume to create a closed sampling system
Gas Analysis	Mass Flow Controller for CO2	FC_4113_01	Closed (0 L/min flow)	
Gas Analysis	CO2 injection line solenoid	SV_4113_01	Closed	
Gas Analysis	CO2 injection line manual over-Ride ball valves	HV_4113_01	Closed	No CO2 gas supplied to inlet solenoid at start of test
Air Lock	Exterior Air Lock Doors	N/A	Closed	
Air Lock	Interior Air Lock Doors	N/A	Open	
Air Lock	Purge Inlet and Vent Solenoid Valves	RV_4100_01, SV_4102_01, SV_4102_02, RV_4101_01, SV_4103_01, SV_4103_02	Closed	
Air Circulation	Main Blower and VFD	BLWR_4111_01, MVFD_4111_01	Running at normal operational speed for mixing (TBD)	
EC/pH	Pressure equilibration valves manually closed		Closed	
Irrigation	Irrigation Pump Inlet Manual Override	HV_4106_02	Closed	
Irrigation	Irrigation Drain Manual Override	HV_4106_03	Closed	
Interface	All interface ports sealed		Sealed	

7.11 Test As-Run Procedure

Date: 31.07.2009 Time:12:12	Test Engineer/operator: Natalia Tikhomirova MPP Supervision: Raul Moyano, Arnaud Fossen

Seq. Nb.	Description	Required/Nominal	Measured/ calculated	Remarks/Calculation (raw data are expected as well as their treatment)	Pass (P) Fail (F)
1	Activate main centrifugal blower VFD to operate at the normal operating speed for mixing (TBD)				P
2	Confirm fan operation through Schneider control system and air velocity sensor (FT_4111_01) output				P
3	With the IRGA sampling (and stabilized) from the interior growing volume, record the initial reading	AT_4113_01 reading ambient CO_2 (350 – 400 ppm)	403 ppm	See deviations table 7.13	P
4	Set the Schneider control system CO_2 demand to 1500 ppm	SV_4113_01 is OPEN	SV_4113_01 is OPEN		P
5	Open the CO_2 line delivery pressure fo 110 kPa	CO_2 tank regulator delivery at 110 kPa			P
6	Open the CO_2 injection (SV_4113_01) override valve	SV_4113_01	SV_4113_01		P
7	Allow the system to equilibrate at 1500 ppm for 2 hours to allow time for equilibration with the passive air pressure compensation bags			The Schneider control system will inject CO_2 until the setpoint is reached	P
8	In the Schneider control system, set CO_2 control to 'manual off' so that no more CO_2 is added to the system				P
9	Allow data collection by the Schneider control system for a minimum of 48 hours				P
10	Calculate the leak rate given the concentration at the beginning of the test and after 24 hours ([CO_2] start – [CO_2] final) / [CO_2] start * 100% = % leakage per day			*Initial: 1524* *Final : 1430* *Leakage rate =6.2%*	P

7.12 Conclusions

The test was successful.

7.13 Deviations

Seq. Nb.	Description of the modification	Justification
	The nominal conditions for AT_4113_01 reading ambient CO_2 should be changed into (350 – 400 ppm ± 30 ppm)	The error of the CAI 600P O_2/CO_2 analyser is 1% full scale, meaning 30 ppm for the configured range of 3000 ppm

8. EC System Functional Testing

8.1 Procedure ID: MPP-HPC1-EC – FT

8.2 Introduction

The aim of this test is to demonstrate and test the operation of the stock injection solenoids, the stock tank injection over-ride manual ball valves, the integrity of stock tanks, the EC sensor and the pressure equilibration manual ball valves.

8.3 Acronyms used in this test plan procedure

EC – Electrical Conductivity

8.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

8.5 Data Log File Names:

MPP_HPC1_EC_FT.txt

8.6 Parts Tested (P&ID Reference):

1. VSSL_4108_01, VSSL_4108_02 (Stock Tanks A and B)
2. SV_4108_01, SV_4108_02 (Stock A and B injection valves)
3. LSL_4108_01, LSL_4108_02 (Stock A and B tank low level switches)
4. HV_4108_01, HV_4108_02 (Stock A and B Injection Manual Over-ride Valves)
5. AT_4108_01 (EC Sensor)

8.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the acceptance criteria that follow are met

Acceptance criteria

Proper functioning of the following parts is demonstrated, according to the conditions noted;

1. Stock Tanks A and B do not show evidence of leakage (VSSL_4108_01, VSSL_4108_02)
2. The functionality of the injection solenoid valves is demonstrated (SV_4108_01, SV_4108_02)
3. The low level switches for the stock tanks are demonstrated (LSL_4108_01, LSL_4108_02)
4. The manual stock injection override valves are demonstrated (HV_4108_01, HV_4108_02)
5. The EC sensor is demonstrated operational

Rejection criteria

The test shall be repeated if the data acquisition looks doubtful or failed completely or if any of the conditions outlined above are not met.

8.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior and interior air lock doors shall be closed in this test (leakage test running concurrently) but no special environment control of the interior of the chamber is required.

8.9 Safety aspects

No special safety considerations have been identified for this test.

8.10 Test set-up

Ancillary Equipment Required for Test:

1. Prepared Stock A and B Solutions (see TN96.3 'Test protocols and procedures for lettuce cultivation')
2. Control system set to record signals from the EC sensor

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Irrigation	Main Irrigation Pump	GP_4106_01	Off	
Irrigation	Manual shut-off valve to chamber	HV_4106_01	Closed	
Irrigation	Irrigation drain manual valve	HV_4106_03	Closed	
Irrigation	Irrigation by-pass isolation valves	HV_4106_04 and HV_4106_05	Open	
Irrigation	Irrigation Pump Inlet Manual Over-Ride Valve	HV_4106_02	Open	
Irrigation	Stock Tanks A and B	VSSL_4108_01, VSSL_4108_02	Filled to capacity with deionized water 24 hours prior to this functional test.	

Irrigation	Hydroponics reservoir	VSSL_4106	Empty	
EC	EC Sensor	AT_4108_01	Logging with Schneider	
EC	Stock Injection Solenoids	SV_4108_01, SV_4108_02	Closed	
EC	Stock Injection Manual Over-Ride valves	HV_4108_01, HV_4108_02	Closed	

8.11 Test As-Run Procedure

Date: 15.07.2009 Time:			Test Engineer/operator: Raul Moyano, Christophe Bourg (Sherpa) MPP Supervision: Natalia Tikhomirova		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Calibrate EC sensor as per manufacturers requirements.				P
2	Check Stock A and B tanks for leakage.			No leakage should be seen in acid/base tanks or allied plumbing lines. Tanks have been filled for 24 hours. Leaks will appear as drops or puddles in and around the tanks and/or feed lines	P
3	Open the Stock A manual injection valve (HV_4108_01)				P
4	Record the state of the Solution A float level sensor as shown in the Schneider control system (LSL_4108_01)			The sensor should read high level	P
5	Using the Schneider control system, set the Stock Solution A valve to ‘manual on’ (VSSL_4108_01)				P
6	Observe Stock Tank A for 5 minutes or until the tank is empty			If water has drained from the tank, the test is successful	P
7	Record the state of the Solution A float level sensor as shown in the Schneider control system (LSL_4108_01)			The sensor should read low level	P

8	Close Stock A manual injection valve (HV_4108_01) and set the control to 'manual off' (VSSL_4108_01) with Schneider				P
9	Open the Stock B manual injection valve (HV_4108_02)				P
10	Record the state of the Solution B float level sensor as shown in the Schneider control system (LSL_4108_02)			The sensor should read high level	P
11	Using the Schneider control system, set the Stock Solution B valve to manual on (VSSL_4108_02)				P
12	Observe Stock Tank B for 5 minutes or until the tank is empty			If water has drained from the tank, the test is successful	P
13	Record the state of the Solution B float level sensor as shown in the Schneider control system (LSL_4108_02)			The sensor should read low level	P
14	Close Stock B manual injection valve (HV_4108_02) and set the control to 'manual off' (VSSL_4108_02) with Schneider				P
EC System Test					
15	The hydroponics reservoir is filled, manually, with approximately 150 L of distilled water from facility source	VSSL_4106 filled to 150 L with dH_2O	VSSL_4106 filled to 150 L with dH_2O	May be done through open top of the reservoir	P
16	Fill Stock Tanks with prepared Stock A and B Solutions.			See TN96.2 'Test protocols and procedures for lettuce cultivation'	P
17	The main irrigation pump is started and set to provide a mixing flow	GP_4106_01 is ON	GP_4106_01 is ON	As the main valve to the hydroponics trays is closed, only use as much power as needed to allow a moderate flow through the bypass line	P
18	Adjust valves HV_4106_04'a' and 'b' to	HV_4106_	HV_410		P

	provide adequate flow through the irrigation bypass pipe and past the EC sensor.	04 valves are opened	6_04 valves are opened		
19	Confirm that the EC sensor is reading less than 100 uS, although this depends on the water source available	AT_4108_01 reading less than 100 uS	0.05 uS		P
20	Open the manual Stock A Tank injection valve	HV_4108_01 OPEN		See deviations table 8.13	P
21	Activate the Stock A injection solenoid using the Schneider control system for 20 seconds	SV_4108_01 is OPEN		See deviations table 8.13	P
22	Confirm that the EC rises – wait until the reading is stable before continuing to the next step			See deviations table 8.13	P
23	Open the manual Stock B Tank injection valve	HV_4108_02 OPEN		See deviations table 8.13	P
24	Activate the Stock B injection solenoid using the Schneider control system for 20 seconds	SV_4108_02 is OPEN		See deviations table 8.13	P
25	Confirm that the EC rises			After both Stock A and Stock B Tanks injection valves were opened for 20 seconds, EC rised from 0.92 to 1.06 See deviations table 8.13	P

8.12 Conclusions

The test was successful.

8.13 Deviations

Seq. Nb.	Description of the modification	Justification
20-25	Test was performed in different way, both valves were opened at the same time.	As both stock solutions during future tests with the crops will be injected at the same time, it was decided to perform test with both valves opening at the same time.

9. pH System Functional Testing

9.1 Procedure ID: MPP-HPC1-pH – FT

9.2 Introduction

The aim of this test is to demonstrate and test the operation of the acid and base injection solenoids, the acid/base tank injection over-ride manual ball valves, the integrity of acid/base tanks, and the pH sensor.

9.3 Acronyms used in this test plan procedure

None

9.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

9.5 Data Log File Names:

MPP_HPC1_pH_FT.txt

9.6 Parts Tested (P&ID Reference):

1. VSSL_4107_01, VSSL_4107_02 (Acid and Base Tanks)
2. SV_4107_01, SV_4107_02 (Acid and Base injection valves)
3. LSL_4107_01, LSL_4107_02 (Acid and Base tank low level switches)
4. HV_4107_01, HV_4107_02 (Acid and Base Injection Manual Override Valves)
5. AT_4107_01 (pH Sensor)

9.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the following conditions are met

Acceptance criteria

Proper functioning of the following parts is demonstrated, according to the conditions noted;

1. The acid and base tanks do not show evidence of leakage (VSSL_4107_01, VSSL_4107_02)
2. The functionality of the injection solenoid valves is demonstrated (SV_4107_01, SV_4107_02)
3. The low level switches for the stock tanks are demonstrated (LSL_4107_01, LSL_4107_02)
4. The manual stock injection override valves are demonstrated (HV_4107_01, HV_4107_01)
5. The pH sensor is demonstrated operational

Rejection criteria

The test shall be repeated if the data acquisition looks doubtful or failed completely or if any of the conditions outlined above are not met.

9.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient. The chamber exterior and interior air lock doors shall be closed in this test (leakage test running concurrently) but no special environment control of the interior of the chamber is required.

9.9 Safety aspects

Concentrated acid and base solutions will be used in this test. Caution and adherence to laboratory safety protocol must be enforced at all times.

9.10 Test set-up

Ancillary Equipment Required for Test:

1. Prepared Acid and Base Solutions as per TN96.3
2. Control system set to record signals from the pH sensor

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Irrigation	Main Irrigation Pump	GP_4106_01	Off	
Irrigation	Manual shut-off valve to chamber	HV_4106_01	Closed	
Irrigation	Irrigation drain manual valve	HV_4106_03	Closed	
Irrigation	Irrigation by-pass isolation valves	HV_4106_04 and HV_4106_05	Open	
Irrigation	Irrigation Pump Inlet Manual Over-Ride Valve	HV_4106_02	Open	

Irrigation	Hydroponics reservoir	VSSL_4106	Empty	
pH	Acid and Base Tanks	VSSL_4107_01, VSSL_4107_02	Each filled to capacity with deionized water 24 hours prior to this test.	No leakage should be seen in acid/base tanks or allied plumbing lines
pH	pH Sensor	AT_4107_01	Logging	
pH	Acid and Base Injection Solenoids	SV_4107_01, SV_4107_02	Closed	
pH	Acid and Base Manual Over-Ride valves	HV_4107_01, HV_4107_02	Closed	

9.11 Test As-Run Procedure

Date: 9.07.2009 Time:			Test Engineer/operator: Raul Moyano, Christophe Bourg (Sherpa) MPP Supervision: Natalia Tikhomirova		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Calibrate pH probe as per manufacturer requirements				P
2	Check Acid and Base reservoirs for signs of leakage			No leakage should be seen in acid/base tanks or allied plumbing lines. Tanks have been filled for 24 hours. Leaks will appear as drops or puddles in and around the tanks and/or feed lines	P
3	Open the Acid manual injection valve (HV_4107_01)				P
4	Record the state of the Acid float level sensor as shown in the Schneider control system (LSL_4107_01)			The sensor should read high level	P
5	Using the Schneider control system, set the Acid valve to 'manual on' (VSSL_4107_01)				P
6	Observe the acid tank for 5 minutes or until the tank is empty			If water has drained from the tank, the test is successful	P

7	Record the state of the Acid tank float level sensor as shown in the Schneider control system (LSL_4107_01)			The sensor should read low level	P
8	Close acid manual injection valve (HV_4107_01) and set the control to ‘manual off’ (VSSL_4107_01) with Schneider				P
9	Open the Base manual injection valve (HV_4107_02)				P
10	Record the state of the Base tank float level sensor as shown in the Schneider control system (LSL_4107_02)			The sensor should read high level	P
11	Using the Schneider control system, set the Base valve to ‘manual on’ (VSSL_4107_02)				P
12	Observe the Base tank for 5 minutes or until the tank is empty			If water has drained from the tank, the test is successful	P
13	Record the state of the Base tank float level sensor as shown in the Schneider control system (LSL_4107_02)			The sensor should read low level	P
14	Close Stock B manual injection valve (HV_4107_02) and set the control to ‘manual off’ (VSSL_4107_02) with Schneider				P
pH System Test					
15	Fill the hydroponic reservoir with approximately 150 L of distilled water from facility source	VSSL_4106 filled to 150 L with dH_2O	VSSL_4106 filled to 150 L with dH_2O	May be done through open top of the reservoir	P
16	Fill Acid and Base Tanks with prepared Solutions.			See TN 96.3	P
17	The main irrigation pump is started and set to provide a mixing flow	GP_4106_01 is ON	GP_4106_0 1 is ON	As the main valve to the hydroponics trays is closed, only use as much power as needed to allow a moderate flow through the bypass line.	P

18	Adjust valves HV_4106_04'a' and 'b' to provide adequate flow through the irrigation bypass pipe and past the pH sensor.	HV_4106_04 valves are opened	HV_4106_04 valves are opened		P
19	Confirm that the pH sensor positioned on the by-pass line is logging	AT_4107_01	AT_4107_01	Baseline pH level is dependent upon the water source	P
20	Open the manual Acid Tank injection valve	HV_4107_01 OPEN	HV_4107_01 OPEN		P
21	Using the Schneider control system, activate the Acid injection solenoid for 10 seconds	SV_4107_01 is OPEN	SV_4107_01 is OPEN	Acid injection solenoid was activated for 1 second See deviations table 9.13	P
22	Confirm that the pH sensor readings decrease after injection	AT_4107_01 reading decreasing	Reading decreased from 6.52 to 6.35	See deviations table 9.13	P
23	Close the manual Acid Tank injection valve	HV_4107_01 Closed	HV_4107_01 Closed		P
24	Allow pH to stabilize before proceeding to the next step				P
25	Open the manual Base Tank injection valve	AT_4107_02	AT_4107_02		P
26	Using the Schneider control system, activate the Base injection solenoid for approximately 10 seconds	HV_4107_02 OPEN	HV_4107_02 OPEN	Base injection solenoid was activated for 1 second See deviations table 9.13	P
27	Confirm that the pH sensor readings increase after injection	SV_4107_02 is OPEN	Reading increased from 6.05 to 6.45	See deviations table 9.13	P
28		AT_4107_01 reading increasing	AT_4107_01 reading increasing		P
29	Close the manual Base injection valve	HV_4107_02 Closed	HV_4107_02 Closed		P

9.12 Conclusions

The test was successful.

9.13 Deviations

Seq. Nb.	Description of the modification	Justification
21-22, 26-27	Acid and Base injection solenoids were activated only for 1 second each	Activation of solenoids for 1 second was enough in order to see the changes in pH sensor readings

10. Irrigation Sub-System Functional Testing

10.1 Procedure ID: MPP-HPC1-IRRIGATION-FT

10.2 Introduction

The purpose of this test is to demonstrate the integrity of the nutrient reservoir and plumbing, to confirm flow among water cascade spigots, and to ensure operation of the main irrigation pump and outlet flow sensor.

10.3 Acronyms used in this test plan procedure

None

10.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

10.5 Data Log File Name:

MPP_HPC1_IRRIGATION_FT.txt

10.6 Parts Tested (P&ID Reference):

1. GP_4106_01 (Main Irrigation Pump)
2. FT_4106_01 (Irrigation Flow Sensor)
3. HV_4106_01 (Manual shutoff to chamber)
4. Irrigation manifold in chamber
5. HV_4106_02 (Irrigation Pump Inlet Manual Override)
6. HV_4106_03 (Irrigation Drain Manual Override)
7. HV_4106_04 and HV_4106_05 (Irrigation By-pass Isolation Valves)
8. HV_4106_05, HV_4106_06, HV_4106_7, HV_4106_8 (Manifold Balancing Ball Valves)
9. VSSL_4106 (Nutrient Reservoir)

10.7 Acceptance/rejection criteria

General

The test is considered successful when the following conditions are met

Acceptance criteria

1. There are no fluid leaks along the irrigation lines of in the reservoir
2. The total flow rate delivered to the trays is 3 L/min or greater as shown by the flow sensor

Rejection criteria

The test fails if any of the conditions for test success noted above are not met.

10.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient.

10.9 Safety aspects

No specific safety aspects are noted

10.10 Test set-up

Ancillary Equipment Required for Test: None

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Irrigation	Nutrient reservoir	VSSL_4106_01	Filled with 160L of deionized water	
Irrigation	All manual valves	All HV_ series valves in 4106 are open	All valves open	
Irrigation	Flow Sensor	FT_4106_01	Factory calibrated	

10.11 Test As-Run Procedure

Date: 12.11.2009 Time:			Test Engineer/operator: Natalia Tikhomirova MPP Supervision: Raul Moyano		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Install growing trays in chamber.				P
	Activate irrigation pump	GP_4106_01 is ON	GP_4106 _01		P

			is ON		
2	Set irrigation pump speed controller stepwise until a minimum of 3 L/min of flow is observed in the Schneider control system overview screen			Speed can be adjusted to provide a visually adequate flow	P
4	Adjust balancing valves to provide a reasonably balanced flow across the four irrigation spout manifolds				P
5	Confirm reading of irrigation flow sensor	FT_4106_01 reading	19.17 L/min 10.13 L/min	19.17 L/min with sensor bypass closed 10.13 L/min with sensor bypass open	P
6	Confirm that flow is at or above 3 L/min and that there is water coming out of each of the spouts along the irrigation manifolds				P
7	Deactivate irrigation pump	GP_4106_01 is OFF	4.32 L/min	Due to offset of the sensor, zero flow shows 4.32 L/min. This offset should be corrected with software modification.	F

10.12 Conclusions

The test was successful except the offset in irrigation flow sensor, to be corrected.

10.13 Deviations

Seq. Nb.	Description of the modification	Justification

11. Thermal Control Sub-System Functional Testing

11.1 Procedure ID: MPP-HPC1-TEMPERATURE/HUMIDITY-FT

11.2 Introduction

The purpose of this test is to confirm operation of the growing volume temperature and humidity sensors, the fluid integrity of both the hot and chilled water coils and service lines, confirmation of operation of the 3 way proportional valves and the functionality of temperature sensors positioned on the coils and water service inlet and exit lines.

11.3 Acronyms used in this test plan procedure

None

11.4 Applicable documents

Technical Annex to SOW ref: TEC-MCT/2005/3466/In/CP
TN 85.71 including P&ID

11.5 Data Log File Name:

MPP_HPC1_TEMPERATURE_HUMIDITY_FT.txt

11.6 Parts Tested (P&ID Reference):

TT 4112_04 - _012 (Growing volume temperature sensors)
AT 4112_01 - _03 and TT 4112_01 - _03 (growing volume humidity and temperature sensors)
S3CV_4112_01 and S3CV_4112_02 (water service line control valves)
TT_4112_13 - _18 (water service line entry and exit temperature sensors, coil surface temperature sensors)

11.7 Acceptance/rejection criteria

General

The test shall be repeated if the data acquisition looks doubtful or failed completely
The test is considered successful when the following conditions are met:

Acceptance criteria

The functional test is deemed successful if:

- all temperature sensors (TT_4112_Series) are shown to be functional
- all humidity sensors are shown to be functional
- The proportional valves may be opened with induction from external signal

Rejection criteria

The test has failed if any of the conditions above are not met

11.8 Environmental requirements

Normal ambient conditions in temperature, pressure and gas composition are sufficient.

11.9 Safety aspects

No special safety issues have been identified for this test.

11.10 Test set-up

Ancillary Equipment Required for Test: None

Verification prior to test performance: confirmation of settings in the Table 1.

Sub-system	Components concerned	Tag (P&ID)	Status at start	Remark/setpoint
Air-Flow	Blower/VFD	BLWR_4111_01 MVFD_4111_01	ON	Operation under normal chamber conditions and Schneider system control
Air handling	Chilled recirculated water must be available and below 10ºC Hot recirculated water must be available and higher than 45ºC			
Pumps	Must be connected and running			

11.11 Test As-Run Procedure

Date: 19.11.2009 Time:			Test Engineer/operator: Natalia Tikhomirova MPP Supervision: Arnaud Fossen		
Seq. Nb.	Description	Required/ Nominal	Measured/ calculated	Remarks/Calculation	Pass (P) Fail (F)
1	Record sensor readings from the Schneider 'HPC System Overview' screen.			Sensors that are not functional will show a reading of 'Failed' instead of	P

				the actual sensor value. Sensor function passes if ‘Failed’ is not present.	
2	Module A		T __20.62ºC__ RH 52.9%_____		P
3	Module B		T 21.29ºC _ RH _48.91%____		P
4	Module C		T _20.94 ºC RH _52.48%___		P
5	Heat exchanger		T_{src}_48.06 ºC T_{loop}_27.08 ºC T_{exit} 30.36 ºC		P
6	Condensing coil		T_{src}_9.42ºC T_{loop}_16.83 ºC T_{exit} 16.79ºC		P
7	Cold rad		T _21.14 ºC _		P
8	Hot rad				P

			T 21.15ºC __		
9	Hydroponic Solution Temperature		T _23.01ºC		P
10	Cold valve (S3CV_4112_01) function. In the Schneider control system, set the cold valve to manual 100% open		T_{loop}_9.61ºC _ T_{exit} 11.76 ºC _ $T_{cold\ rad}$ _13.61 ºC	Temperatures in these sensors should decrease over time	P
11	Set cold valve (S3CV_4112_01) to manual 0% open				P
12	Hot valve (S3CV_4112_02) function. In the Schneider control system, set the hot valve to manual 100% open		T_{loop} 57.91ºC T_{exit} 38.12 ºC $T_{hot\ rad}$ 37.73 ºC	Temperatures in these sensors should increase over time	P
13	Set hot valve (S3CV_4112_02) to manual 0% open				P

11.12 Conclusions

the test was successful.

11.13 Deviations

Seq. Nb.	Description of the modification	Justification

12. Crop Testing

12.1 Introduction

The purpose of this test is to characterize system functioning with a growing crop. The primary criteria to be tested are temperature, humidity control and CO_2 control. Depending on crop development, pH and EC control may be utilized as well.

12.2 Consumables required for Operational Testing with Crops

Consumables:

- Rockwool – small cubes – Grodan AO 36/40 6/15W (2940 in carton)
- Rockwool – large cubes – Grodan Delta 4G 42/40(383 in carton)
- Seed germination trays and covers
- Lettuce seeds – cv. Grand Rapids

Equipment:

- Balance for micro-nutrient and salt measurement (500 g ± 0.01g)
- Solution stock storage tanks (2 x 20 L tanks with spigot, PP)
- Seedling nutrient storage tank (1 x 10 L with spigot, PP)
- Solution transfer tank (1 x 200 L tank, PP)
- Submersible pump (5 L min^{-1} or greater) and connection tubing
- Growth cabinet for seedling establishment (300 µmol s^{-1} m^{-2} PAR minimum). HPC can be substituted, if available, with all lamps on and appropriate temperature/RH setpoints
- Higher plant chamber (1 or more)
- Magnetic stirring plate, stirring bars
- Tweezers

12.3 Solution Preparation

The chamber design allows for the use of a common nutrient solution (single reservoir) feeding all age classes of the crop in staged culture and all trays in batch culture. Studies using the nutrient solution formulation tabled below have been successfully used in staged and batch culture of beet and lettuce with periodic solution dumping. For the present crop test, solution dumping was not performed. For more detailed instruction on solution preparation, please refer to TN96.3.

Table 1. Typical hydroponics nutrient solution used in HPC studies.

Component	Mol. Wt. (g)	Feed Strength (mM)
Stock A		
$Ca(NO_3)_2\cdot 4H_2O$	236.16	3.62
$FeCl_3\cdot 6H_2O$	270.30	0.08
Na- EDTA	372.24	0.10
Stock B		
$MgSO_4\cdot 7H_2O$	246.48	1.00
KNO_3	101.10	5.00
$NH_4H_2PO_4$	115.08	1.50
$(NH_4)_2SO_4$	132.00	1.00
Micronutrients		
H_3BO_3	61.83	0.02
$MnSO_4\cdot H_2O$	169.01	0.0050
$ZnSO_4\cdot 7H_2O$	287.54	0.0035
$CuSO_4\cdot 5H_2O$	249.68	0.0008
H_2MoO_4 (85% MoO_3)	161.97	0.0005

The nutrient solution is made using concentrated stocks solutions. Once made, the nutrient solution is pumped into the main NDS tank and the irrigation system is started once the seedlings have been added to the growing trays.

12.4 Germination, Emergence, Thinning, Planting

Plant individual seeds in Rockwool cubes rinsed with deionized water and place under a clear cover beneath a suitable lighting source. The seeds are watered regularly (daily) with a diluted feed stock solution. After emergence the clear cover is removed. Rockwool and trays for germination may be readily obtained from local greenhouse suppliers. Fourteen days after planting, the seedlings can be transferred to larger Rockwool blocks to be placed in the HPC1 growing trays and moved into the chamber.

As this is a batch culture test, all troughs will be loaded into the chamber at one time. Once in position, the irrigation system is activated. Samples of hydroponic solution should be tested for EC and pH daily to verify HPC1 sensors.

12.5 Crop growth

Once the chamber is loaded, the controller is programmed to provide the following environment conditions for the entire period of crop grow-out (11 days).

CO_2 Demand – 1000 ppm
Temperature – 26/20 º C (day/night)
Humidity – 60% day, 70% night
EC – 2.0 mS/cm
pH 5.9
O_2 – not controlled
Light Intensity – All lights operational

12.6 Analysis of Net Carbon Exchange Rate and Assessment of Model Performance

The computer controller maintains CO_2 concentrations at demand levels during day-light hours through the automated injection of pure CO_2 through a mass flow controller. The amount of time the mass flow controller is on, recorded by the Schneider control system as seconds of injection time, is used to estimate net carbon gain of the developing crop stand. If a suitable amount of time for crop growth permits, NCER can be calculated.

12.7 Harvest

As this is a shortened and basic functional test of the HPC with plants, harvest parameters are not required. Should time and equipment allow, the following can be performed for the purpose of training and practice:

1. At the end of the growing period (variable depending on time requirements for other HPC activities), each individual plant is harvested and separated into edible and inedible fractions. Fresh weight and leaf area for leaf material is recorded.
2. Leaf material and roots, removed from Rockwool cubes, are placed in paper bags in a drying oven for approximately 1 – 14 days at 60º C, depending on the drying oven and plant material.
3. Dry weights of all plant parts is recorded.
4. Tissue samples are to be collected for % C, H, O, N, S, P determination.
5. A carbon balance is determined from the NCER estimates obtained above, the dried biomass and measured carbon content.

12.8 Test results

The results of the functional test in HPC1 with a batch culture of lettuce (*Lactuca sativa* L. cv. Grand Rapids) performed at the UAB MELiSSA pilot plant in Barcelona, Spain, are given below. Lettuce seeds were sown in small rockwool cubes on August 6, 2009. The chronology of the events for the following 14 days of seedling establishment and initial development can be found in Appendix 1.
Although short temperature and humidity deviations took place during plants germination and initial growth (see Appendix 1), in 14 days after sowing no plants damage was observed and in conclusion it was decided to use those seedlings for crop test. One hundred seedlings were transplanted into larger rockwool cubes and placed in the HPC1 on August 21, 2009. The closed chamber test was performed over an eleven day period between August 21, 2009 and September 1, 2009.

12.8.1 HPC Operation

During eleven days of crop test in HPC1 some errors of HMI, temperature and humidity control were observed. Several times HMI was frozen and it was necessary to reboot the server and the client. Also, during transition from night to day temperature and humidity control mode was disabled due to differences between day and night set points and alarm system of the controller. In particular on August, 28 approximately during 45 minutes temperature and humidity control was disabled temperature in the chamber reached 33.5ºC and relative humidity was 70%. However after additional tuning of the controller above-mentioned errors were not observed anymore. Visually plants did not seem to be affected and the test was continued until September, 1 2009. There were 2 dates of plants harvesting. On August 28, 2009 20 lettuce plants were harvested in order to compare data with the results of previous crop test with Argus controller. After the crop test was continued with the remaining 80 plants, which were harvested in September 1, 2009.

12.8.2 Environment Control

First of all it should be mentioned that there was a mistake in the historical data collect configuration for all tags of the CIVb_HPC1 during the first 4 days of the crop test as the limit of data compression was 0.5 (default value). Then if data did not change a difference of 0.5 units the value was not recorded. This mistake partially affected calculation of average (table 2) and also gave wrong vision of control during first 4 days of the test, especially for EC and pH (Figure 5).
During the tuning of Schneider system it was observed that when all the lamps were on and set point of temperature was 26º C it was not possible to reach relative humidity of 75% and even 70-65% due to physical incompatibility between temperature and relative humidity. For this reason set point for relative humidity at day time was 60% (table 2). For night period humidity was maintained at 70%.

As it could be seen from table 2 night temperature during the test could be controlled quite well. However it was difficult to reach required day temperature (26º C) and day humidity (60%) during the first 6 days of the test and for this reason higher deviation of day temperature and day relative humidity could be observed (table 2, figure 1). According to Sherpa peer review it was not possible to maintain both temperature at 26°C and RH at 60 % during the first days of crop test due to low plants transpiration. It would be better to ask for 50 % as relative humidity set point, or allow temperature to be higher. Relative humidity 60 % and day temperature 26°C could be reached during the 7th day after beginning of crop test, when plants were bigger.

Table 2. Environmental control setpoints and parameter readings averaged over an 11 day period of closure of HPC1 growing 80 lettuce plants

Parameter	Setpoint	Actual	Standard deviation
Temperature			
Day	26º C	26.4º C	0.7º C
Night	20º C	20.1º C	0.1º C
Humidity			
Day	60 %	59.9 %	0.6 %
Night	70 %	70.1 %	0.5 %
Carbon Dioxide	1000 µmol mol^{-1}	1002.6 µmol mol^{-1}	6.2 µmol mol^{-1}
pH	5.9	5.80	0.01
EC	2.0 mS cm^{-1}	2.03 mS cm^{-1}	0.06 mS cm^{-1}
MELiSSA Facility Environment Control			
Temperature			
Day	N/A	25.1º C	1.3 º C
Night	N/A	22.9º C	0.4 º C
Chilled water source	<10º C	9.2º C	0.7 º C
Hot water source	>45º C	47.0º C	0.7 º C

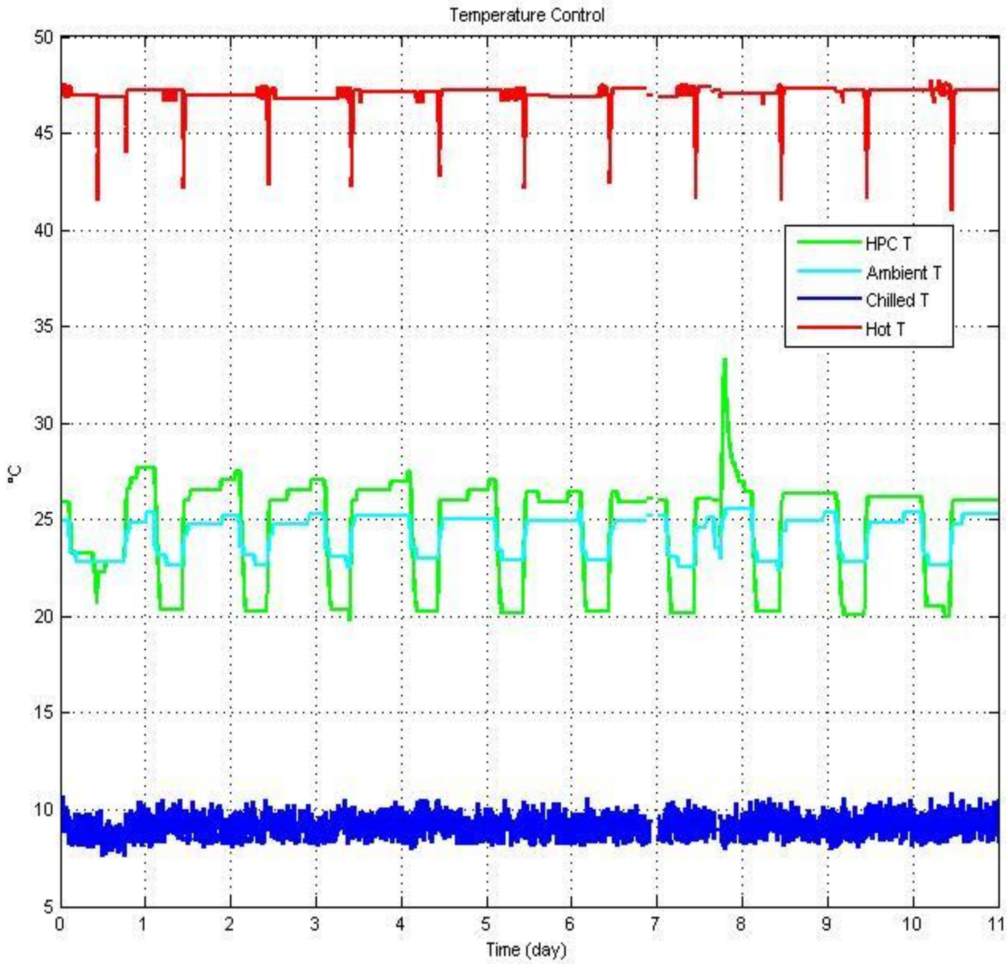


Figure 1. Temperature control in the HPC and UAB MELiSSA pilot plant over the 11 day period of closure

As it can be seen from figure 1 values recorded for ambient temperature in HPC room changed at the same time when changed temperature in HPC1. That artefact was caused by the location of the sensor, which was placed in a zone where the lights loft air was exhausted and the values recorded were wrong.

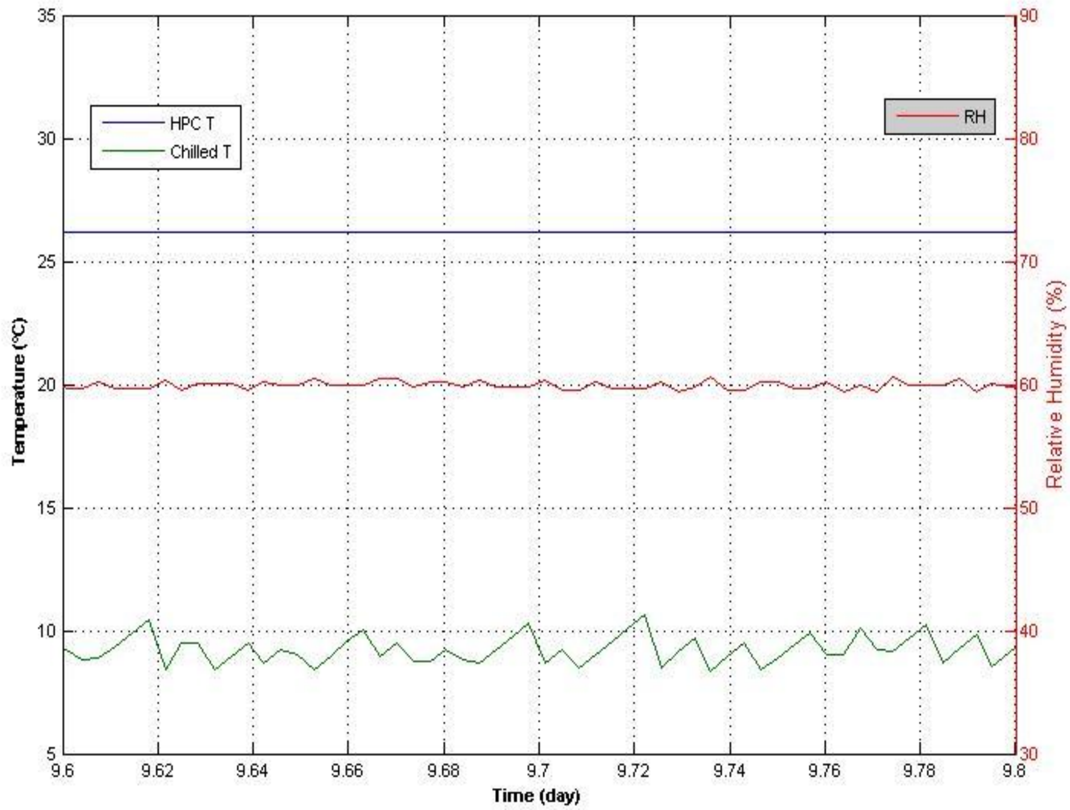


Figure 2. Relative humidity control in HPC1 and temperature control of UAB chilled water

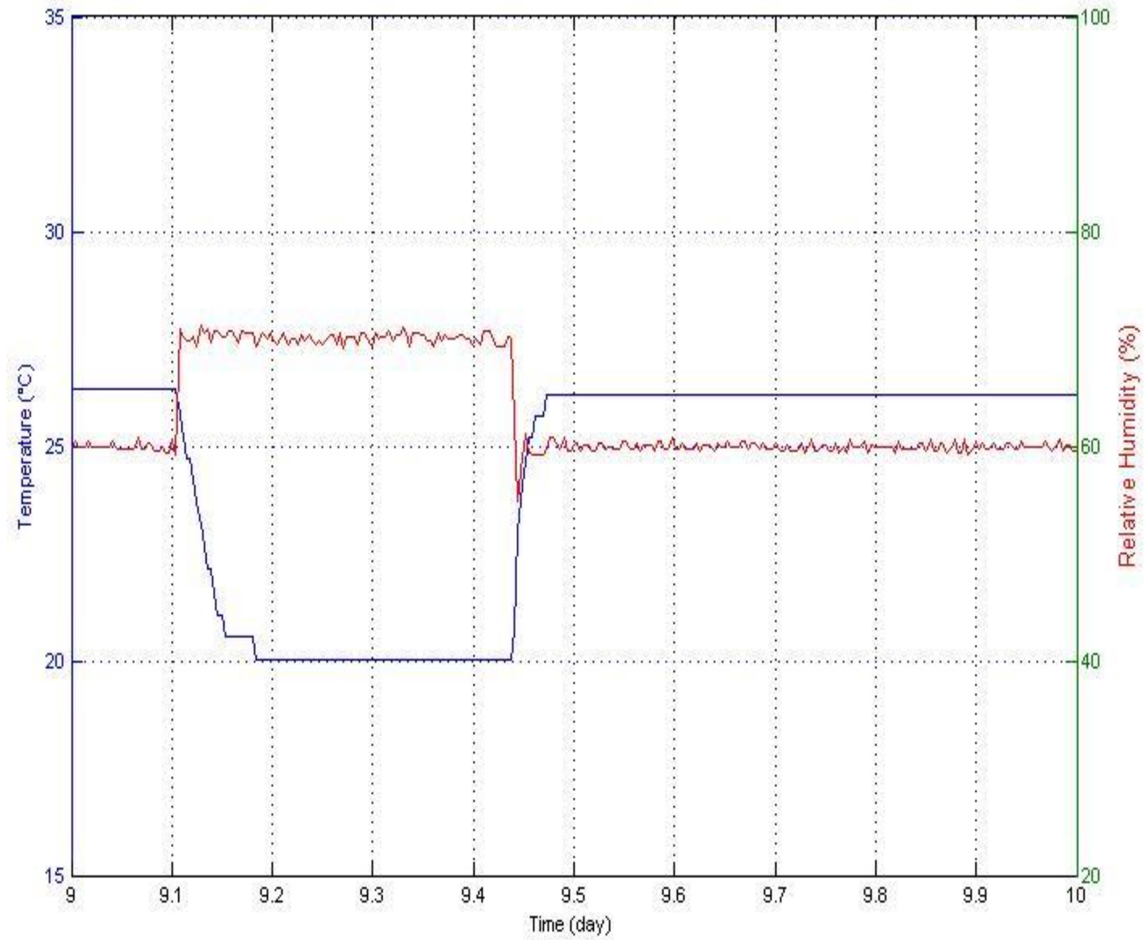


Figure 3. Control of temperature and humidity during the transition from day to night

During transition from day to night it took about 90 minutes for temperature stabilisation and about 10 minutes for relative humidity stabilisation (Figure 3). Transition from night to day was faster concerning temperature – only 25 minutes for stabilisation and a little longer for humidity – about 15-20 minutes.

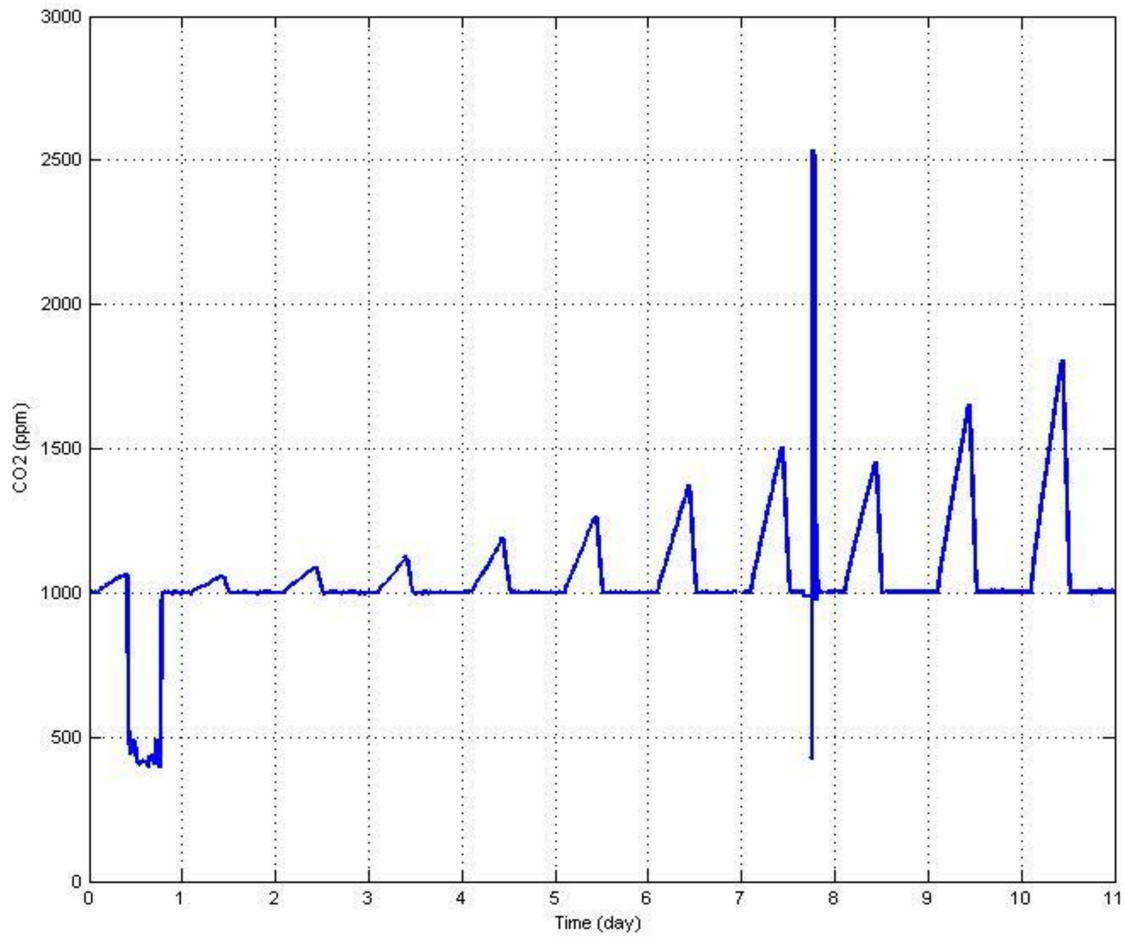


Figure 4. Carbon dioxide control over the full 11 day closed crop growth test in HPC1

Control of CO_2 in the chamber was performed well. During the day time the level of CO_2 in the chamber was maintained at 1002.6±6.2 ppm due to CO_2 injections (table 2). At night time CO_2 was not controlled and released by plants during respiration. Progressive release of CO_2 by plants from night to night was correlated with plants growth along the test (Figure 4).

Decrease of CO_2 concentration between day_0 and day_1 (Figure 4) was connected with termination of the seedlings phase and opening of HPC1 in order to start the crop test. On the 7^{th} day after closing the chamber was opened and plants were harvested partially, the consequences of that operation could be seen from figure 4. Increase of CO_2 concentration up to 2500 ppm was connected with poor mixing of CO_2 in the chamber since the blower was disabled for short period of time. After the blower was enabled CO_2 level decreased.

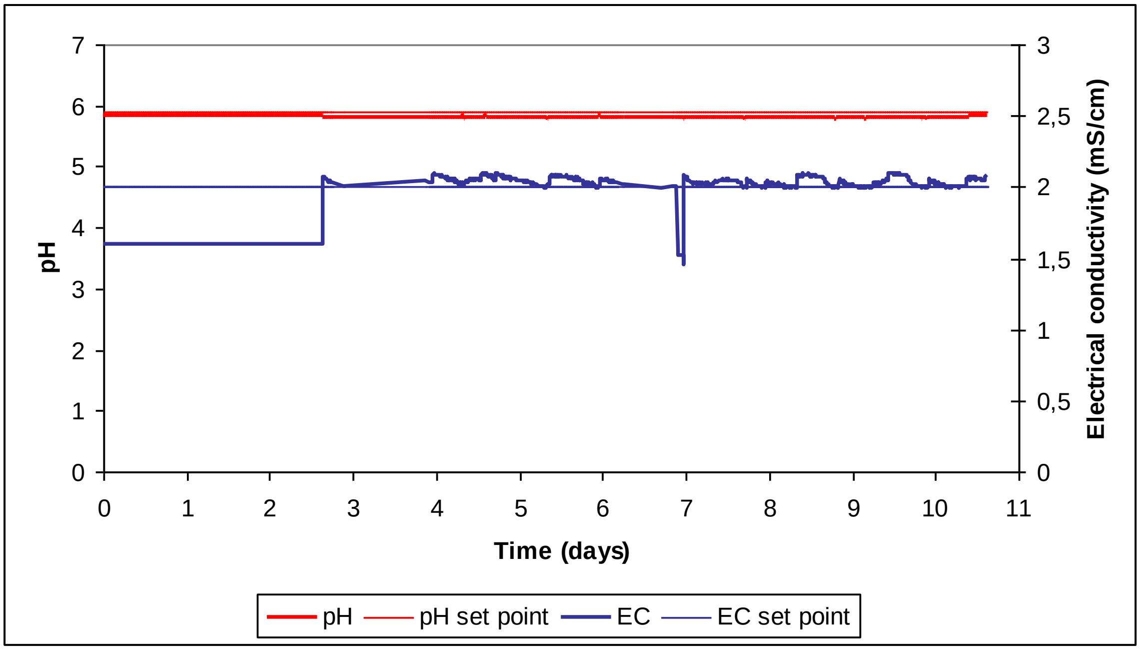


Figure 5. EC and pH control over an 11 day period in HPC1

Since mistake in configuration of the historical data collect took place in the beginning of the test, it was difficult to evaluate control of EC and pH during the first 4 days of the test (Figure 5). However after the error correction, analysis of the data recorded showed that control of EC and pH during the rest of the test was quite well (Figure 5). Decrease of EC value on the 7^{th} day of the crop test was connected with disabling of the irrigation system in order to harvest part of the plants. In line with the properties of EC probe the measurements are correct only when the probe is completely submerged in a solution. For this reason when irrigation mode was stopped and few quantity of the nutrient solution left in the tube where EC probe was installed, deviation in EC measurement was observed. Deviation in pH measurement also took place, however in connection with pH electrode's properties the deviation of pH values was less than of EC ones.

12.8.3 Conclusions

It can be concluded that control of all environmental conditions in the chamber in general was performed well during the crop test (table 2). However some deviation in day temperature and humidity control was observed (table 2, Figure 1). Even though 60% of relative humidity is acceptable level of humidity for lettuce cultivation, it is on the limit with minimum allowable humidity for favourable lettuce cultivation. As it was observed in the beginning of the test, even 60% of humidity could not be reached during the first days of plants cultivation. It could be also concluded that fluctuations of day temperature and day relative humidity were not linked to utilities temperatures values but were connected with physical incompatibility between temperature and relative humidity (Figure 1, 2). Probably, possible way for solving this problem is to decrease set point of temperature to 24°C as lettuce is cold resistant plant and can be successfully cultivated at day temperature of 22-24°C.

Since the values recorded for ambient temperature in HPC room were wrong (Figure 1) the measurement of Plant operating temperature should be improved during future crop growth experiments with the HPC.
Also, higher air velocity in module B in comparison with the other modules could be observed during the test. Moreover, no humidity and temperature sensor was installed in growing area of module B and it was impossible to compare these parameters in module B with the other modules.

12.8.4 Crop test results on dry and fresh biomass of lettuce plants after 7 days of growth (21/08/09-28/08/09)

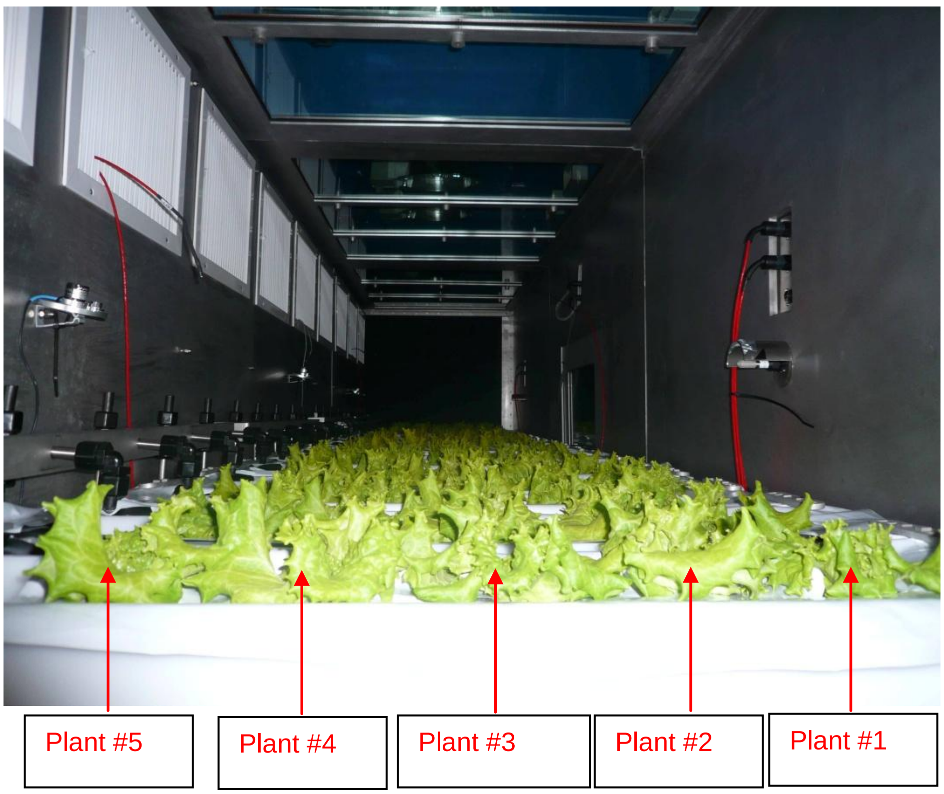


Figure 6. Lettuce crop resulting from 7 days of growth in HPC1 at UAB, from module A to module C

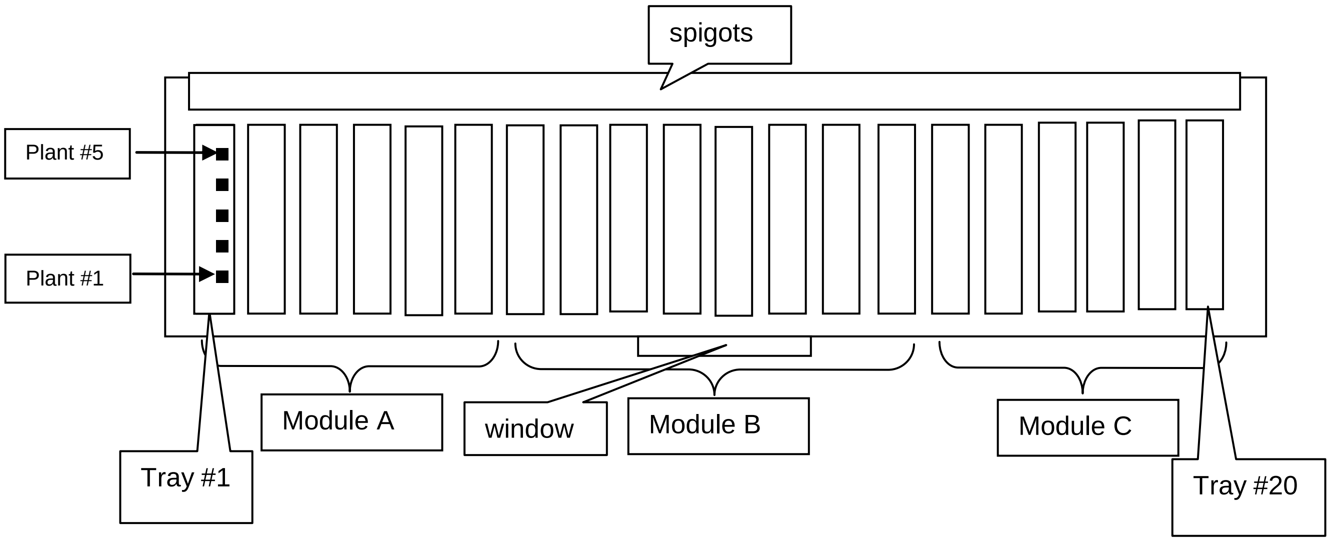


Figure 7. Schematic top view of HPC1 with plants and trays numbering

Like for the previous crop test with Argus controller (TN 96.5) schematic top view of HPC1 is given in figure 7. The plants were harvested from module A to module C, from tray #1 to tray #20. After 7 days of closure only central plant #3 in each tray was harvested. For more detailed instruction of plants harvesting please refer to TN 96.4. In order to know plants shoot biomass distribution along the chamber it was decided to present the data as it is can be observed from figure 8. That data was available only for shoot fresh biomass, as after weighing the plants fresh weight, they were mixed and 7 samples were prepared for further lyophilization (TN 96.4).

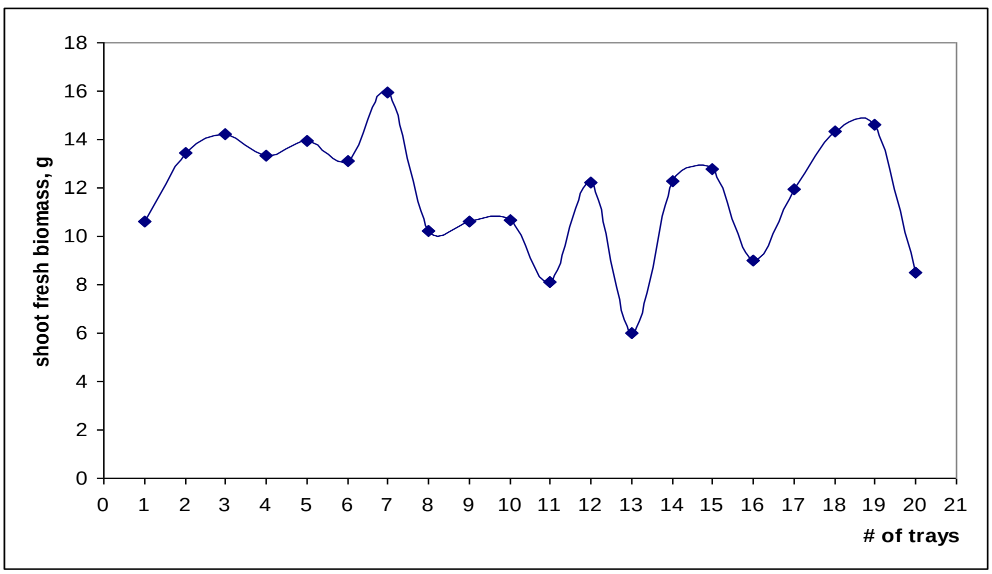


Figure 8. Lettuce shoot fresh biomass (g) of plant # 3 along the chamber (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C) after 7 days of closure

Average shoot fresh and dry biomass per each module was also estimated in order to compare lettuce production between modules A, B and C (Figure 9).

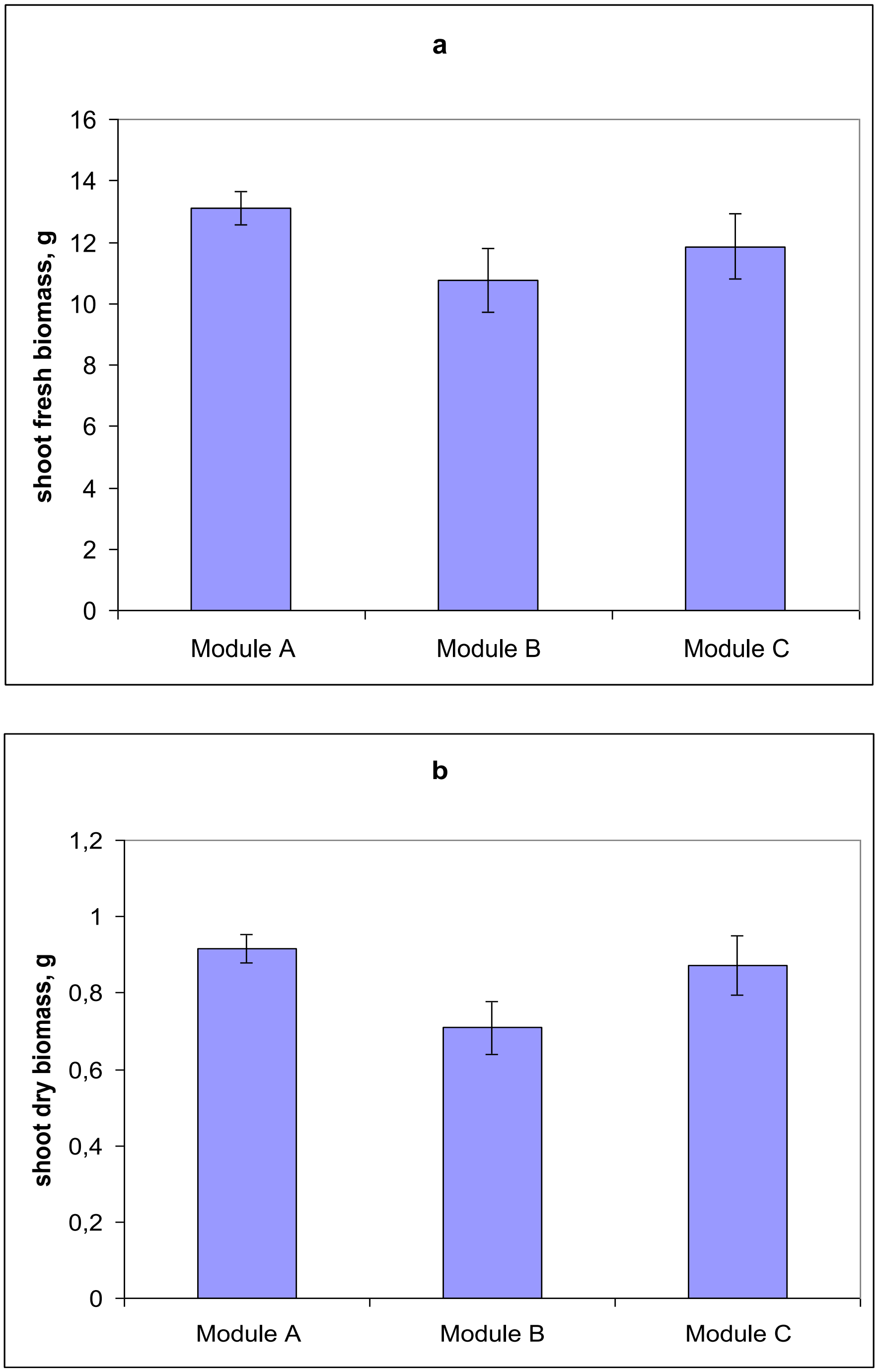


Figure 9. Lettuce shoot biomass (g) of plant # 3, average per module after 7 days of closure: a – fresh biomass; b – dry biomass

After 7 days of plants cultivation in HPC1, dispersion of central plant (grown in row #3 along the chamber, Figure 6, 7) fresh biomass along the chamber could be observed (Figure 8). The highest biomass dispersion was observed in module B like in the previous experiment with Argus controller (TN 96.5), however the lowest biomass was observed for the plants grown in trays #11, 13, 16 and 20 (Figure 8). These results apparently confirm previously stated assumption concerning presence of unequal environmental conditions in the chamber. Average shoot dry biomass of the plants in module B was reliably lower than in module A and C. However no reliable difference in average fresh plants biomass could be observed between plants of module B and C due to higher water content in plants of module B (Figure 9).

12.8.5 Crop test results on dry and fresh biomass of lettuce plants after 11 days of growth (21/08/09-1/09/09)

Figure 10. Lettuce crop resulting from 11 days of growth in HPC1 at UAB, from module A to module C

After 11 days of closure the plants were harvested in the same order as after 7 days of closure, from module A to module C (Figure 7). Since plant #3 was harvested previously, only 4 plants per tray were weighed: plant #1,2,4,5 (Figure 10).

In order to analyze plants distribution along the chamber, like for the previous crop test with Argus controller (TN 96.5) it was decided to present data of lettuce shoot dry and fresh biomass for each plant number (plant #1, 2, 4, 5, see Figure 10) separately. Distribution of plant #1 shoot dry and fresh biomass is given on figure 11.

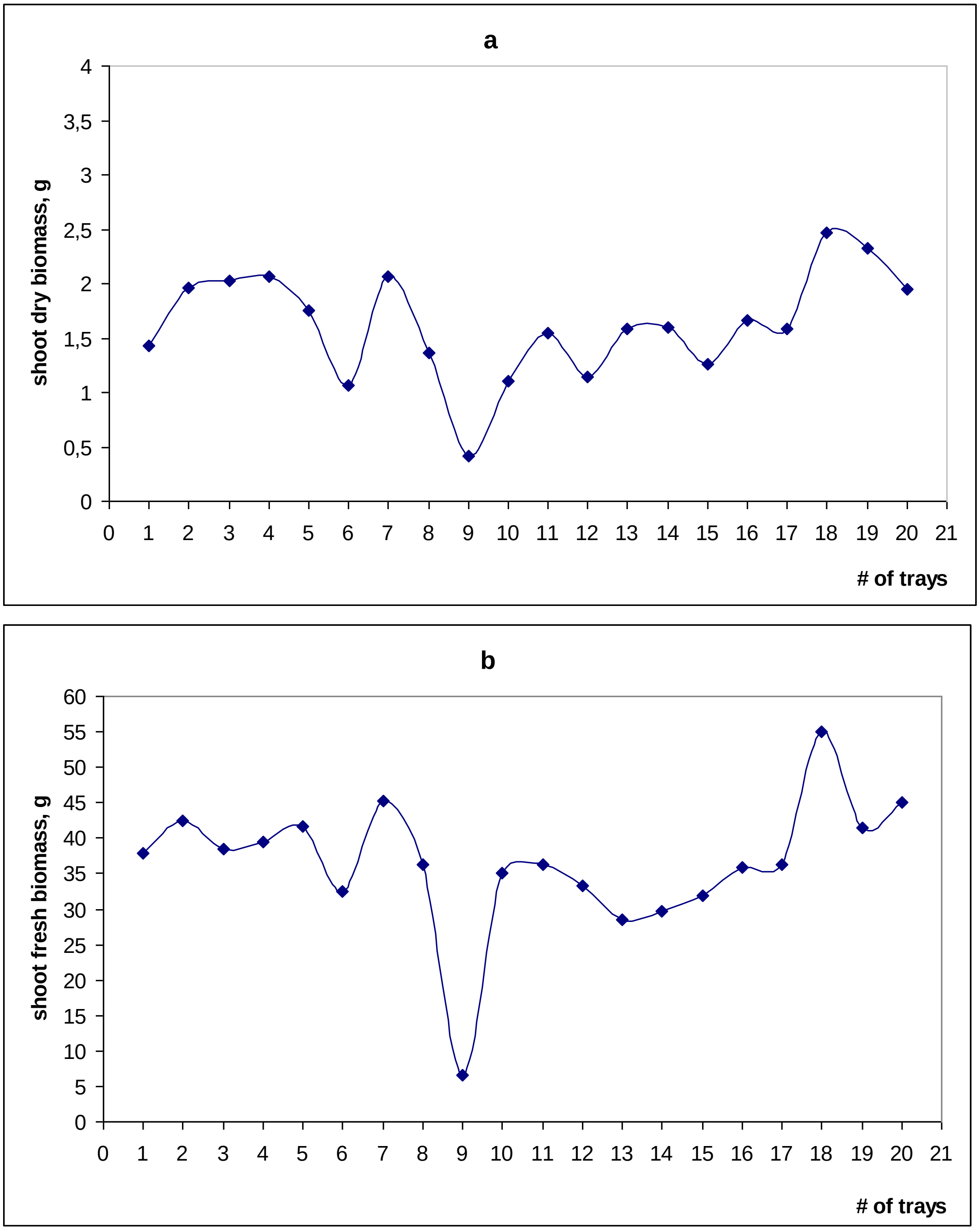


Figure 11. Lettuce shoot biomass (g) of plant # 1 along the chamber after 11 days of closure: a – dry biomass; b – fresh biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)

As it can be seen from figure 12, shoot dry biomass of plant #2 is given only for certain trays, as plants from other trays were mixed with plant #4 and 7 samples were prepared for further lyophilization (TN 96.4).

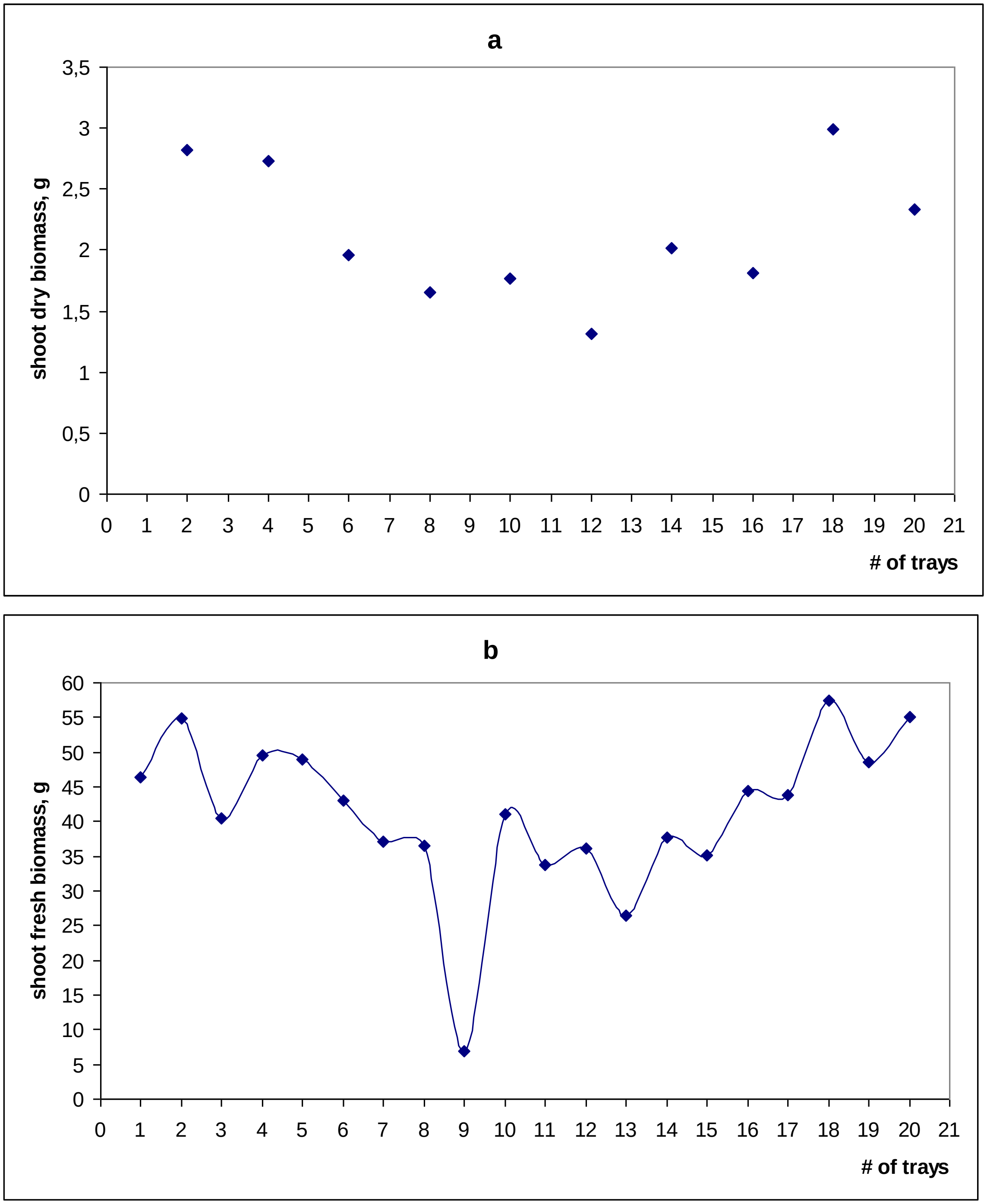


Figure 12. Lettuce shoot biomass (g) of plant # 2 along the chamber after 11 days of closure: a – dry biomass (data available only for trays #2,4,6,8,10,12,14,16,18, 20); b – fresh biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)

Absence of shoot dry biomass data of plant #4 for some trays (Figure 13) was also connected with samples preparation for lyophilization (TN 96.4).

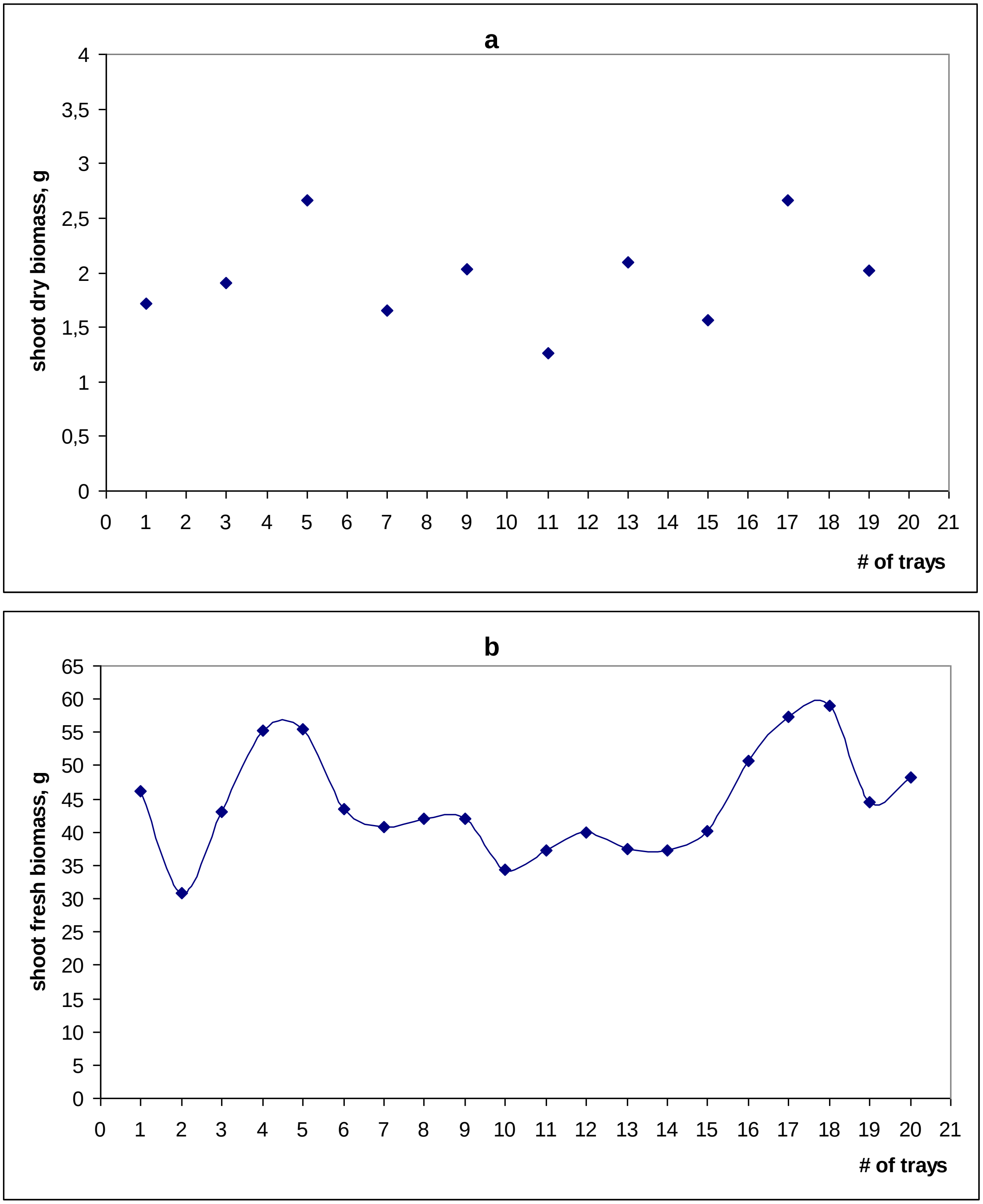


Figure 13. Lettuce shoot biomass (g) of plant # 4 along the chamber after 11 days of closure: a – dry biomass (data available only for trays #1,3,5,7,9,11,13,15,17,19); b – fresh biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)

Distribution of plant #5 along the chamber is given on figure 14.

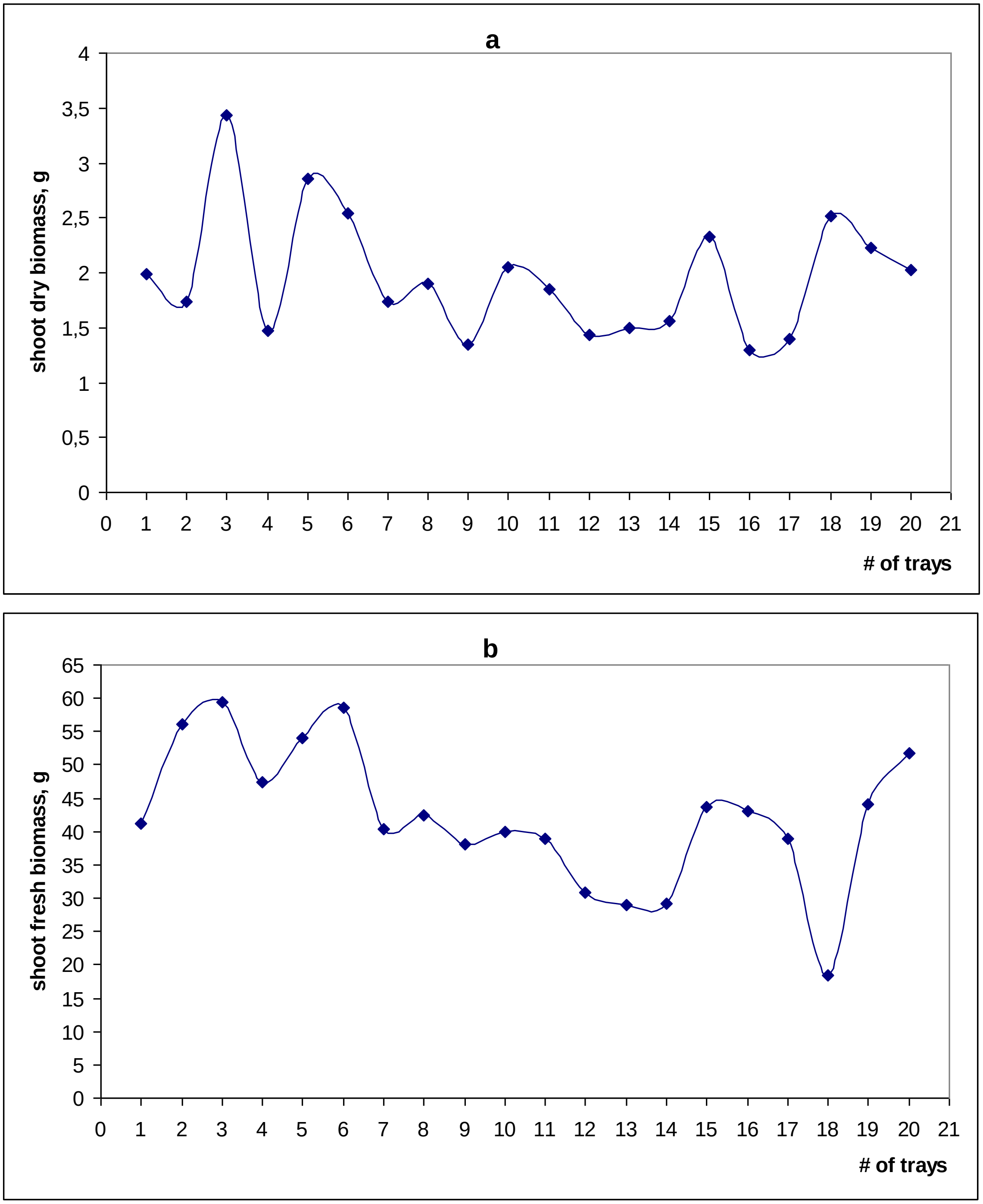
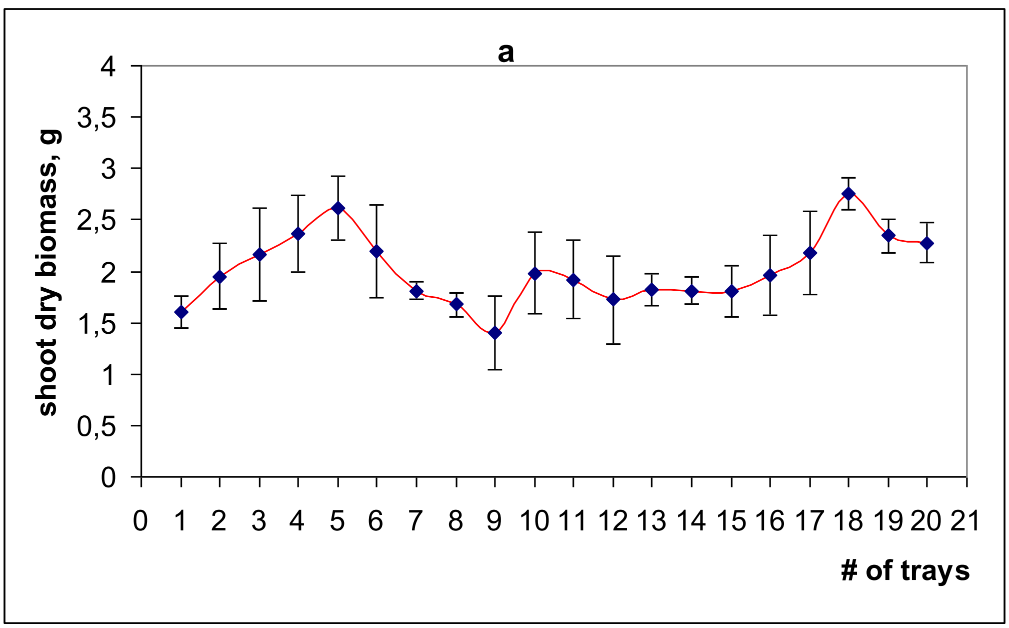


Figure 14. Lettuce shoot biomass (g) of plant # 5 along the chamber after 11 days of closure: a – dry biomass; b – fresh biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)

After 11 days of plants cultivations the same tendency like 3 days before could be observed. Values of plants biomass along the chamber differed (Figures 11-14). Lowest biomass of plant #1 and plant #2 (Figure 10) was observed in tray #9 (Figure 11,12), for the plant # 4 – in trays # 2 and 10 (Figure 13), and for the plant # 5 – in trays # 12-14 (Figure 14). Difference in lowest dry and fresh biomass was observed for plants #1 and #5 in some trays due to difference in plants water content. The results showed inequality of environmental conditions along the chamber and not only in module B but in some areas of module A and C. Comparison of results on lettuce production at crop test with Argus controller (TN 96.5) and with Schneider controller showed that distribution of all plants along the chamber was not the same for the tests, however similar results were observed for the plants #1 and #2. Notably decrease of lettuce shoot dry biomass of plant #1 was observed in trays # 7, 13, 16 at crop test with Argus controller (TN 96.5, Figure 15) whereas at the crop test with Schneider controller decrease of lettuce shoot dry biomass of plant #1 was observed in trays # 6, 12 and 15 (TN 96.11, Figure 11). For the plant #2 decrease of lettuce shoot fresh biomass in tray #13 was observed at both crop tests (TN 96.5, Figure 16; TN 96.11, Figure 12). Apparently heterogeneity of environmental conditions existed in those areas of HPC1 (mostly module B) that affected plants located next to one of the walls of the chamber (in front of the air grids and the spigots). The reasons of that heterogeneity should be studied in the future crop tests.

In order to know average plants biomass per each tray along the chamber, average shoot dry and fresh biomass is given on Figure 15.



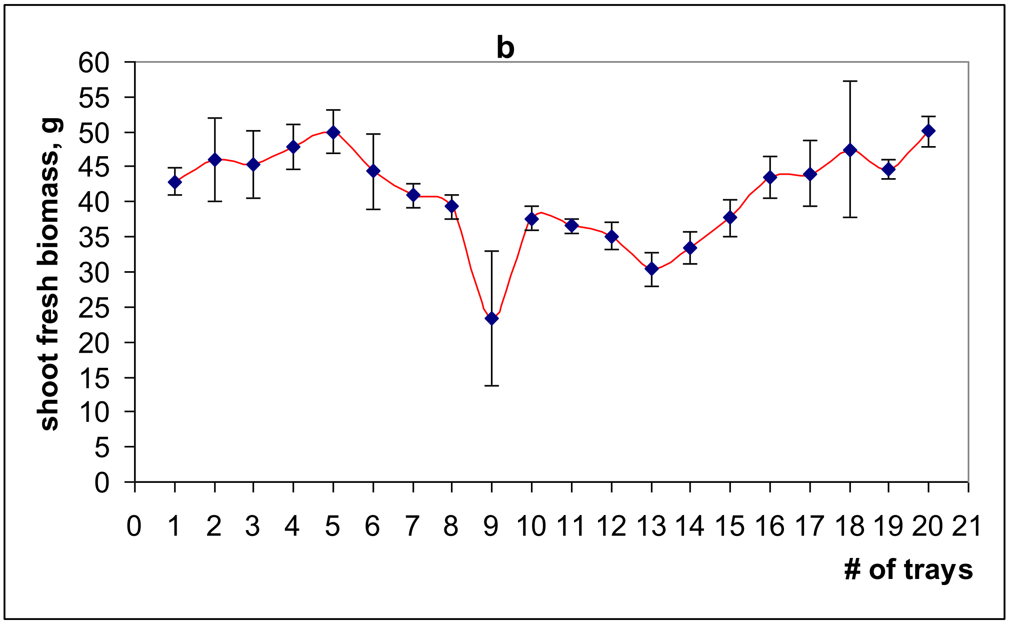


Figure 15. Lettuce shoot biomass (g) of plants #1,2,4,5, average per tray after 11 days of closure: a – dry biomass; b – fresh biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)

For better visualization of all plants distribution in HPC1, the data is given in 3D format (Figure 16).

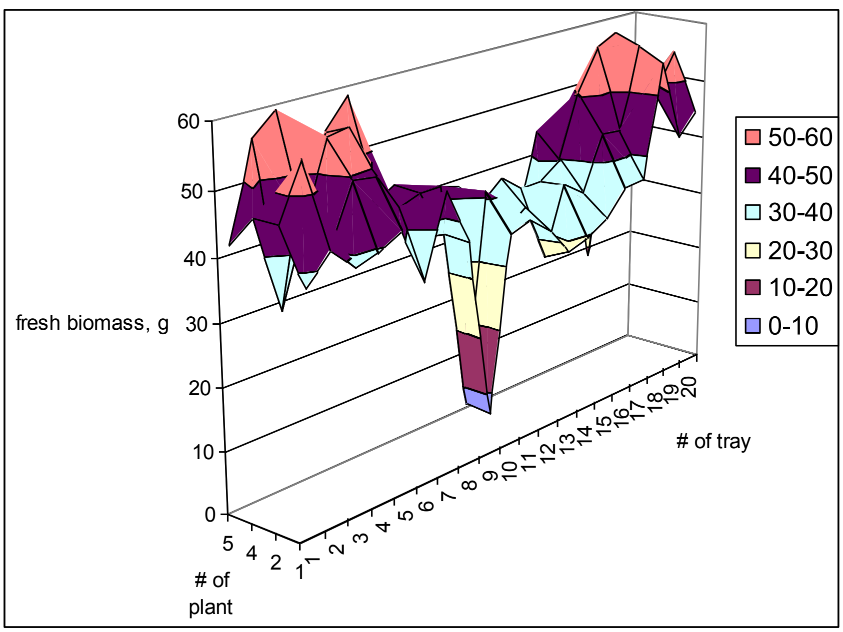


Figure 16. Lettuce shoot fresh biomass (g) of plants #1,2,4,5, after 11 days of closure

Average lettuce shoot dry and fresh biomass per each module of HPC1 is given in figure 17.

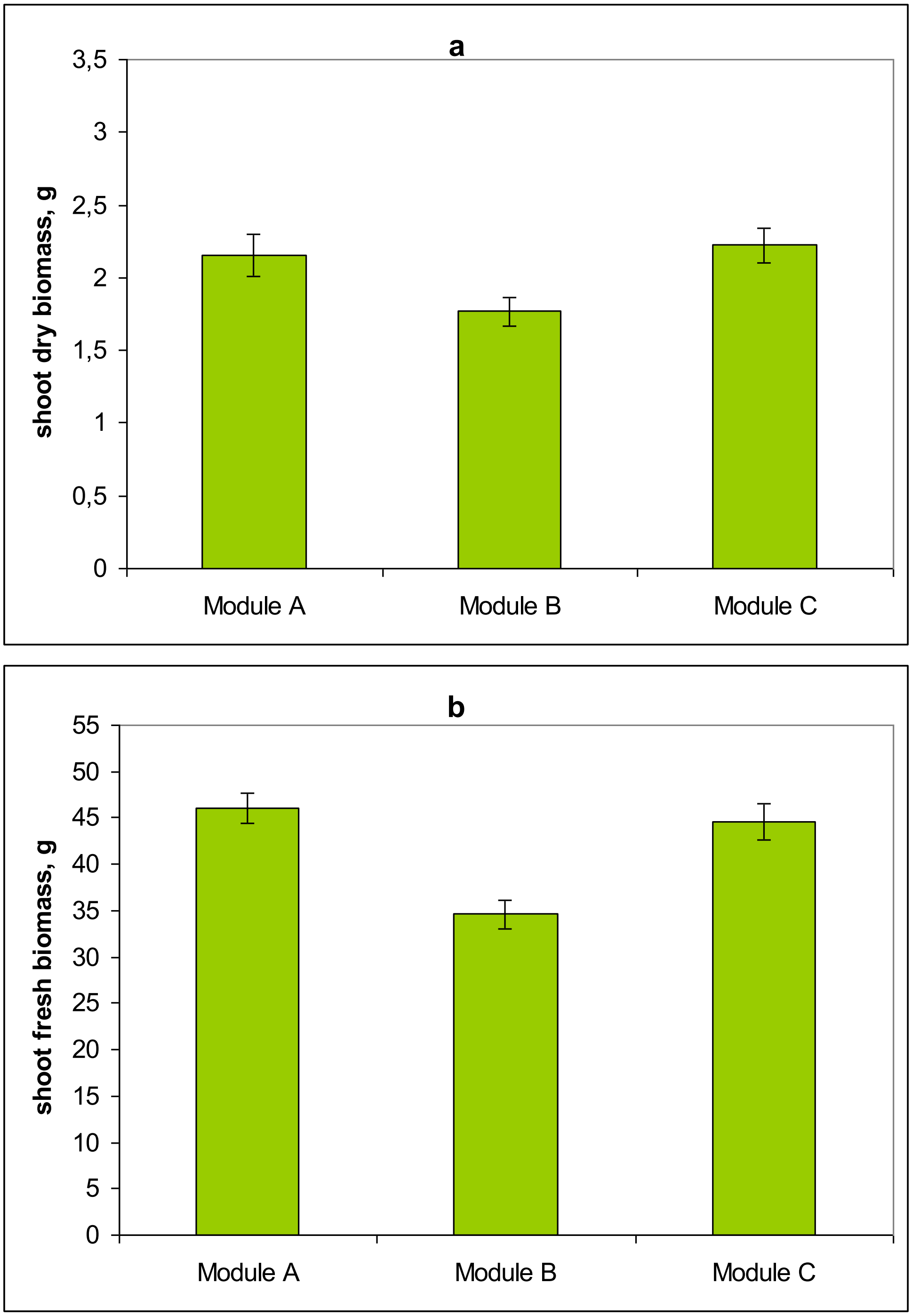


Figure 17. Lettuce shoot biomass (g) of plants #1,2,4,5, average per module after 11 days of closure: a – dry biomass; b – fresh biomass (trays #1-6 – module A, trays #7-14 – module B, trays #15-20 – module C)

Averaging of plants dry biomass per tray showed high dispersion along the chamber in trays #2-6, 9-12 and 15-16 (Figure 15). This result was connected with difference in environmental conditions for the plants along the trays in these particular areas and probably was mostly connected with different conditions for the plants grown in the central and boundary parts along chamber. Decrease of plants biomass in module B at crop test with Schneider controller was observed (Figure 16) in comparison with the results obtained at crop test with the Argus controller (TN 96.5, Figure 22).

Decrease of the plants average both dry and fresh biomasses in module B in comparison with modules A and C could be observed (figure 17). The results obtained could be connected with higher air velocity in module B that could entail increase of plants transpiration and discrepancy between water uptake of whole plant and level of transpiration, that could provoke water stress and deficiency of nutrients during the first phases of growth. Another possible reason could be lack of nutrients for the plants due to different water flow from different spigots. Even though rockwool is high saturable substrate and there was continuous running irrigation during the test, it is necessary to perform a test of each spigot water flow before next crop test in order to exclude this reason of plant production decrease.

12.8.6 Mineral and elemental composition of lettuce plants and mineral composition of nutrient solutions used for lettuce cultivation

Table 3. Mineral composition of nutrient solution in the beginning (estimated) and after 3, 7 and 11 days of crop test (average of 3 samples) (mg/L)

Nutrients (mg/L)		Initial composition (estimated, TN 96.3)	After 3 days of test start up	After 7 days of test start up	After 11-days of test start up
Macro nutrients	Ca	140	223±14*	217±1*	240±1*
	Mg	20	53±18	35.5±0.2	38.3±0.2
	K	200	464±153	316±2	338±2
	P	50	91±27	61.3±0.4	56.6±0.3
	S	60	139±47	93.3±0.5	99±1
	N-NO_3	170			
	N-NH_4	50	94±21	67±2	46±2
Micro nutrients	Fe	4.5	8.1±0.6	7.9±0.1	9±1
	B	0.2	0.5±0.2	0.296±0.002	0.33±0.02
	Zn	0.2	0.6±0.2	0.392±0.003	0.39±0.02
	Mo	0.06	0.09±0.03	0.053±0.002	< 0.04 – 0.04
	Mn	0.3	0.6±0.2	0.3949±0.0002	0.426±0.001
	Cu	0.05	0.11±0.04	0.074±0.001	0.080±0.004

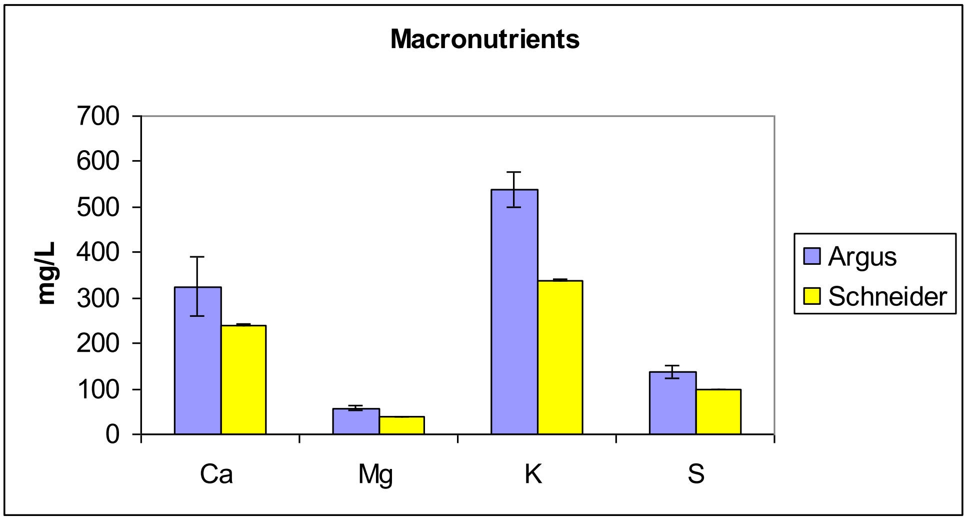
	Na	4.9	9±1	7.82±0.05	19±9
	Cl	8.5			

* - uncertainty is dispersion observed on 3 samples of nutrient solution

The samples of the nutrient solutions were taken for further analyses 3 times during the crop test: on the third, seventh and eleventh days after crop test start up. Each time before taking the samples the irrigation was disabled, then a sampling cup (200 mL) was 3 times filled with the nutrient solution with subsequent outpouring of the solution. Then 3 samples in a raw were taken for the analysis (volume of each sample was 200 mL). The resulted obtained showed very high dispersion over the three samples of nutrient solution taken on the third day of the crop test (table 3). That dispersion was connected with higher minerals content in the first sample of the nutrient solution in comparison with the following two. The reason of this problem was not clear but could be connected with poor mixing of the nutrient solution at the moment of taking the first sample.

After 3 days from the test start up, concentration of macro- and micronutrients increased 1.5-2 times, depending on nutrient, in comparison with initial nutrient concentration (table 3). However it should be taken into consideration that initial concentration on nutrients was not analyzed but estimated according to recipe of nutrient solution (TN 96.3). Moreover, according to TN 96.3 electro conductivity (EC) of nutrient solution should be maintained on the level of 2 mS/cm. In the beginning of the test it was observed that EC of new solution, after preparation according to abovementioned recipe, was about 1.7 mS/cm and after control system activation, stock solutions were added in order to reach EC set point. In order to be sure about real values of nutrients concentration, it is necessary to take samples of nutrient solution after its preparation in the next crop test.

After 4 more days of crop test, in comparison with the previous date of taking samples (7 days after test start up) concentration of all nutrients in the solution decreased. After 11 days of crop test concentration of the nutrients in the solution except phosphorus, ammonia nitrogen and molybdenum, was higher than after 7 days. Probably speed of P, $N\text{-}NH_4$ and Mo uptake was higher than speed of addition of those elements into the solution. In the future experiments it will be necessary to take samples of the nutrient solution more often in order to have an idea about nutrients uptake by plants at different phases of growth and in order to work out methods of more efficient correction of nutrients concentration in the solution.



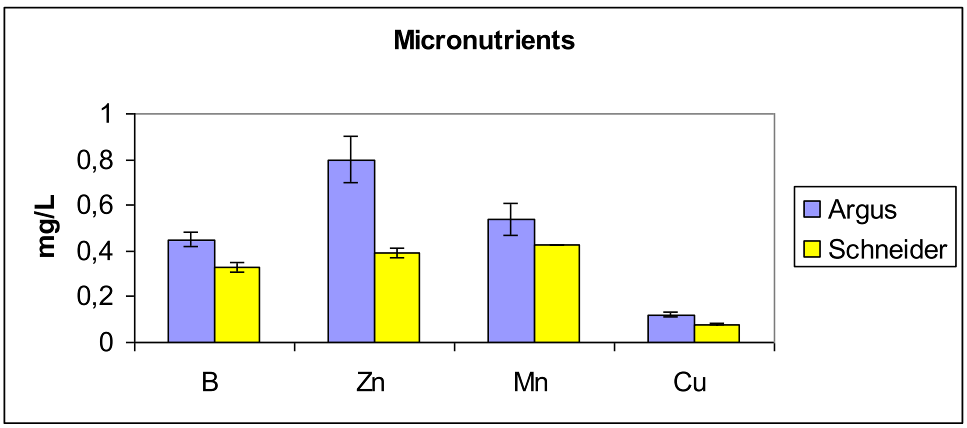


Figure 18. Comparison of some minerals concentration in the nutrient solutions in the end of the crop tests with Argus and Schneider controllers (mg/L)

It should be mentioned that concentration of more than half of nutrients in the nutrient solution in the end of 11-days crop test with Schneider controller was lower in comparison with 11-days crop test with Argus controller (Figure 18), but no deficiency in nutrients in comparison with nutrient solution recipe was observed.

Like in the previous crop test with Argus controller (TN 96.5) in order to know mineral and elemental composition of the seedlings before starting crop test (so-called t_0), the seedlings that were not used for the crop test, were harvested, weighed, lyophilized and analyzed. For the beginning of the crop test the seedlings were used in the age of 15 days. Since the test was started on Friday, remained seedlings were not harvested but were introduced into an incubator with low PAR intensity and left until Monday in order to have seedlings for being able to start a crop test again (in case of plants damage on weekend). Thus the seedlings were harvested at the age of 18 days after sowing. The quantity of the seedlings totaled 65 and their total fresh weight was 54,12 g, total dry weight after lyophilization was 2.4 g. This crop phase is called as Treatment 1 (table 4 and following).

Treatment 2 are lettuce shoots, located in the central raw along HPC1 (plant #3, Figure 6), harvested after 7 days of crop test (TN 96.4).

Treatment 3 are lettuce shoots of plant #2 (Figure 10, samples were taken from trays #1,3,5,7,9,11,13,15,17,19) and plant #4 (Figure 10, samples were taken from trays #2,4,6,8,10,12,14,16,18, 20), harvested after 11 days of crop test (TN 96.4).

Table 4. Mineral composition of lettuce shoot, harvested at different phases of vegetation

Nutrients		Treatment 1	Treatment 2	Treatment 3
Macronutrients (% dw)	Ca	1.69±0.04*	1.10±0.03**	1.01±0.02**
	Mg	0.40±0.01	0.31±0.01	0.28±0.01
	K	6.9±0.1	6.1±0.1	5.8±0.1
	P	1.12±0.02	0.79±0.02	0.81±0.01
	S	0.47±0.01	0.43±0.01	0.43±0.01
	N	6.8±0.1	5.7±0.1	5.9±0.1
Micronutrients (mg % dw)	Fe	39±6	19±5	14±1
	B	3.4±0.1	3.0±0.1	2.89±0.04
	Zn	8.6±0.2	5.9±0.2	6.1±0.1
	Mo	0.22±0.01	0.27±0.01	0.24±0.01
	Mn	10.3±0.4	5.9±0.3	5.9±0.2
	Cu	2.1±0.7	1.8±0.7	2.3±0.6
	Na	97±5	30±2	28±1

* - uncertainty for Treatment 1 was calculated by averaging of errors of Treatment 2 and Treatment 3 as only one sample was taken for analyses for Treatment 1

** - uncertainty for Treatment 2 and Treatment 3 is dispersion observed on 7 samples of lettuce for each treatment

As it could be seen from table 4, concentration of minerals except Mo and Cu in the shoots of lettuce seedlings was higher in comparison with the plants, harvested after 7 and 11 days of crop test. Probably it is not very correct to compare data obtained from 65 plants (treatment 1) and 20 plants (treatment 2 and 3). Similar tendency was observed after the test with Argus controller (TN 96.5). Concentrations of minerals in lettuce leaves of treatment 2 and treatment 3 were very close. However the same comment like for crop test results with Argus controller (TN 96.5) should be added here. Error of measurements given by laboratory that analyzed samples (University of Barcelona) is 1%, but when the concentration is near the quantification limit the error can increase up to a maximum of 15%. In table 4 error is calculated according to data repeatability, but if error will be increased, no significant difference will be observed for most of nutrients between treatment 2 and treatment 3 and for some nutrients of treatment 1 in comparison with treatments 2 and 3.

Table 5. Content of elements, obtained from CO_2 and water, in lettuce shoots, harvested at different phases of vegetation (% dw)

Treatment	C	H
Treatment 1	35.4±0.3	4.99±0.04
Treatment 2	39.0±0.4	5.50±0.04
Treatment 3	39.5±0.3	5.45±0.04

Content of carbon and hydrogen in leaves of lettuce seedlings (treatment 1) was lower in comparison with the plants after 7 and 11 days of crop test (treatment 2 and 3) (table 5). Difference in content of these elements in lettuce leaves of treatment 2 and 3 was not reliable. These results show that after 7 days of crop test in closed chamber with maintenance of CO_2 at 1000 ppm and water circulation, content of carbon and hydrogen in lettuce leaves increase in comparison with the initial composition of the plants in the beginning of the test, however 4 days test extension does not significantly influence on content of these elements in the plants.

Table 6. Mineral composition of lettuce shoot at different phases of vegetation, mg

Nutrients		Treatment 1		Treatment 2		Treatment 3	
		Average per plant	Total for 165 plants	Average per plant	Total for 20 plants	Average per plant	Total for 80 plants
Macro-nutrients	Ca	0.62±0.01	103±2	9.1±0.2	181±5	24.9±0.5	1993±39
	Mg	0.15±0.04	25±1	2.55±0.08	51±2	6.7±0.2	540±19
	K	2.54±0.04	419±6	50±1	1008±17	143±2	11412±197
	P	0.415±0.007	69±1	0.79±0.02	15.9±0.4	20.0±0.2	1597±20
	S	0.175±0.004	29±1	3.56±0.08	71±2	10.6±0.2	849±20
	N	2.53±0.04	417±6	47±1	931±16	144±2	11518±195
Micro-nutrients	Fe	0.014±0.002	2.4±0.4	0.19±0.04	3.2±0.8	0.34±0.02	27±2
	B	0.00127±0.00004	0.210±0.006	0.024±0.001	0.49±0.02	0.071±0.001	5.7±0.1
	Zn	0.00318±0.00007	0.52±0.01	0.048±0.002	0.97±0.03	0.150±0.002	12.0±0.2
	Mo	0.000080±0.000004	0.013±0.001	0.0020±0.0001	0.044±0.002	0.0059±0.0002	0.47±0.02
	Mn	0.0038±0.0001	0.63±0.02	0.048±0.002	0.96±0.05	0.144±0.005	11.5±0.4
	Cu	0.0008±0.0003	0.13±0.04	0.015±0.006	0.3±0.1	0.06±0.01	5±1
	Na	0.0121±0.0006	2.0±0.1	0.25±0.02	5.0±0.3	0.69±0.02	55±2

Due to increase of plants biomass with time, quantities of minerals in average lettuce plant also increased with age (table 6). However, at least on the seedlings phase of vegetation, quantity of salts, applied with nutrient solution, was much higher the ability of plants to accumulate these salts (table 7). The same tendency was observed for 11-days crop test with Argus controller (TN 96.5). In the present test, data on quantity of solution, applied during the test, is missing as a counter of stock solutions injection did not work and no other definite information on this issue is available. This will be taken into account for the next test performance. However, based on the previous results with Argus controller and on the present results with seedlings (table 7), it can be assumed that only minor part of the salts, applied with nutrient solution during the test, was accumulated with the plants, the rest stayed in the solution, rockwool cubes and HPC1 liquid loop (trays, pipes).

Table 7. Estimated accumulation of minerals in rockwool, roots and trays at seedlings phase of lettuce vegetation, mg

Nutrients		Treatment 1	
		Applied with nutrient solution	Estimated accumulation in rockwool, roots and trays
Macro-nutrients	Ca	842	739
	Mg	120	95
	K	1203	784
	P	301	232
	S	361	332
	N	1300	883
Micro-nutrients	Fe	27	25
	B	1.2	1.0
	Zn	0.9	0.4
	Mo	0.40	0.39
	Mn	1.8	1.2
	Cu	0.30	0.17
	Na	30	27

12.8.7 Conclusions on lettuce productivity and elemental analysis

All conclusions, concerning lettuce productivity and elemental analysis, drawn after crop test with Argus controller, can be applied also for the test with Schneider controller. But some more observations can be added.

During this test decrease of plants productivity was mostly observed in module B. Also, it was noticed that some leaves of the plants grown in module B were yellowish, that did not take place after the test with Argus controller. Possible reasons could be high air velocity in that area and low water flow, i.e. lack of nutrients for the plants. In order to exclude these possible reasons of plants inhibition it is necessary to do a test of water flow per each spigot and to compare these results with values of plants biomass per tray. Also, in order to improve control of environmental conditions in the chamber, it is necessary to install at least one temperature and humidity sensor in module B. It is necessary to measure air velocity along the chamber in order to know which areas are “problematic”. Ideally, it would be good to have several temperature and humidity sensors installed on the plants level, in order to know not only average temperature and humidity per module, but temperature and humidity, to which plants are exposed, which is the most important.

13. Closed loop tests

The dynamic control Loop tests which had to be tested during the functional tests were :

- Electro-Conductivity
- pH
- CO_2
- Temperature and Humidity in the Chamber

These tests were performed twice :

- without crop
  -with crop

13.1 EC Control Loop

Without Crop. EC can only be increased by the Control System.
Tests performed during the week 15-17 July 2009

13.1.1.Operating Conditions

Chamber Opened or Closed	
Lights Off or On	
Irrigation Mode (HMI) in AUTO → GP_4106_01 is ON	
Level Switch of Nutrient A LSL_4108_01 is OFF	
Level Switch of Nutrient B LSL_4108_02 is OFF	

13.1.2. Variables to be recorded

EC. EC Set Point. Nutrient Valves

13.1.3. Test As-Run Procedure

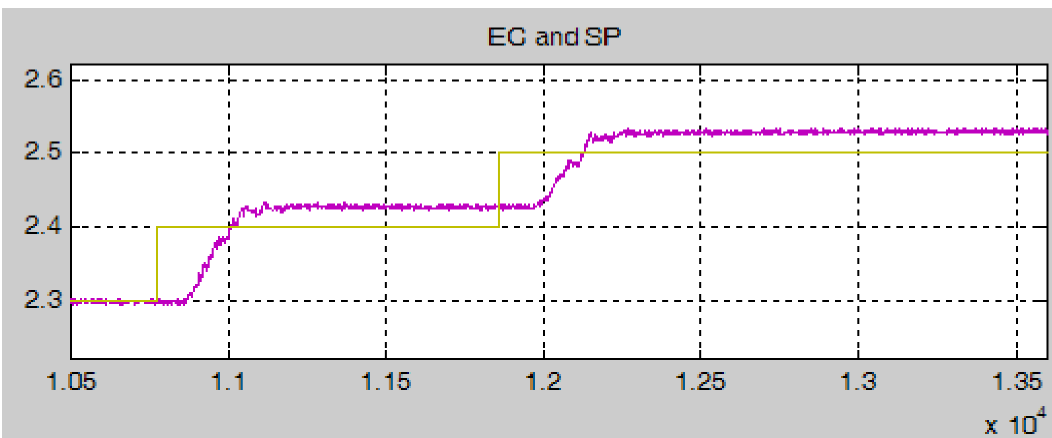
EC should be steady before the test.

Change EC Set Point and wait until the stabilisation

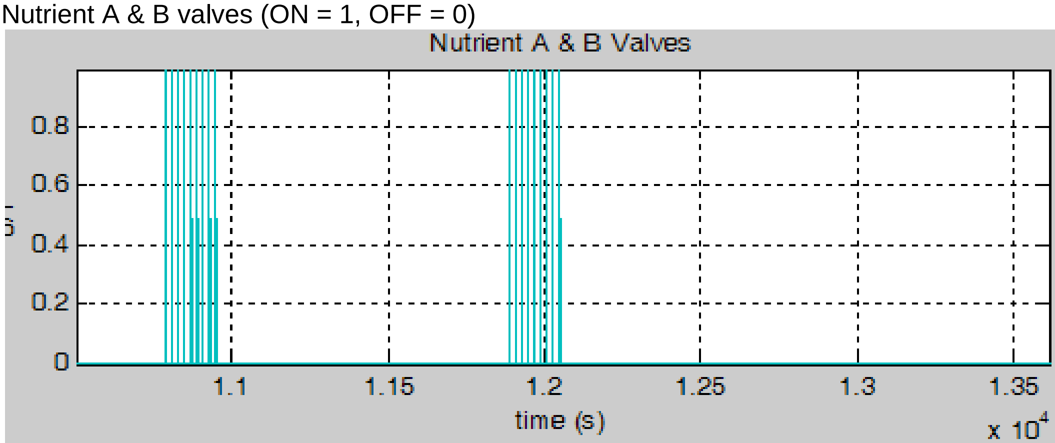
Seq Nb	Description	Required	Remarks	Status

1	(HMI) EC Set Point = EC Measurement Ex : 1.9 mS/cm		EC=2.3	
2	(HMI) EC Mode from OFF to AUTO		OK	
3	Wait for 15 minutes	EC = EC set point	EC=2.3	
4	(HMI) Increase EC Set Point : + 0.1 mS/cm		EC Set point = 2.4	
5	Wait for Stabilisation	Indicate Time for Stabilisation	4 minutes Overshoot : 0.03	OK
6	(HMI) Increase EC Set Point : + 0.1 mS/cm		EC Set Point = 2.5	
7	Wait for Stabilisation	Indicate Time for Stabilisation	5 minutes Overshoot : 0.02	OK

Hereafter EC measurement (purple) and set point (yellow)



Nutrient A & B valves (ON = 1, OFF = 0)



Remark :
- The behaviour will be different with crop as the plants are EC consumers
- There is no way to decrease EC when there is no crop
- There is a strong interaction between EC and pH.
  - If necessary (after crop tests). Control strategy could be changed to take into account these interactions.

13.2 pH Control Loop

Performed during the week 15-17 July 2009

13.2.1 Operating Conditions

Chamber Opened or Closed	
Lights Off or On	
Irrigation Mode (HMI) in AUTO → GP_4106_01 is ON	
Level Switch of Acid Tank LSL_4107_01 is not ON	
Level Switch of Base Tank LSL_4107_02 is not ON	

13.2.2 Variables to be recorded

pH. pH Set Point. Acid and Base Valves

13.2.3 Test As-Run Procedure

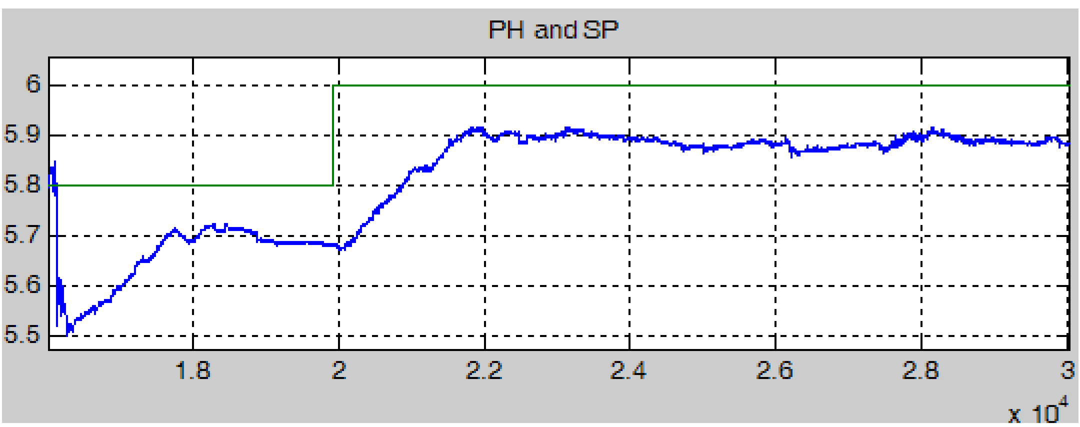
pH should be steady before the test.

Change pH Set Point and wait until the stabilisation.

Seq Nb	Description	Required	Remarks	Status
1	(HMI) pH Set Point = pH Measurement pH Deadzone = 0.1 Ex : pH set point = 5.80			
2	(HMI) pH Mode from OFF to AUTO		OK	
3	Wait for 15 minutes	pH = pH set point +/- Deadzone	pH was not stable. pH set point = 5.8 with DeadZone = 0.1	

			Stabillization at 5.8 – 0.1 = 5.7	
4	(HMI) Increase pH Set Point : + 0.2 Ex : 6.0		+0.2 Set Point = 6.0 Deadzone = 0.1	
5	Wait for Stabilisation	Indicate Time for Stabilisation	Because of Deadzone. Stabilization is at 6.0 – 0.1 = 5.9 28 mn to arrive to the SP	
6	(HMI) Decrease pH Set Point : - 0.4 Ex : 5.6			
7	Wait for Stabilisation	Indicate Time for Stabilisation		

Hereafter, pH (blue) and Set Point (green)



Remark :
- The behaviour will be different with crop as the plants are pH consumers (acidification)
- There is a strong interaction between EC and pH.
  - If necessary (after crop tests). Control strategy could be changed to take into account these interactions.

13.3 CO_2 Control Loop

This test can be performed without and with crop

Without Crop. CO_2 can only be increased by the Control System.

13.3.1 Operating Conditions

Chamber Closed. Curtains closed	
Lights Off or On	
Irrigation Mode (HMI) in AUTO → GP_4106_01 is ON	
Air Blower Mode (HMI) in AUTO → Air Flow (FT_4111_01) around 20 m/s	

13.3.2 Variables to be recorded

CO_2 set point. CO_2
CO_2 mass flow set point and CO_2 mass flow

13.3.3 Test As-Run Procedure

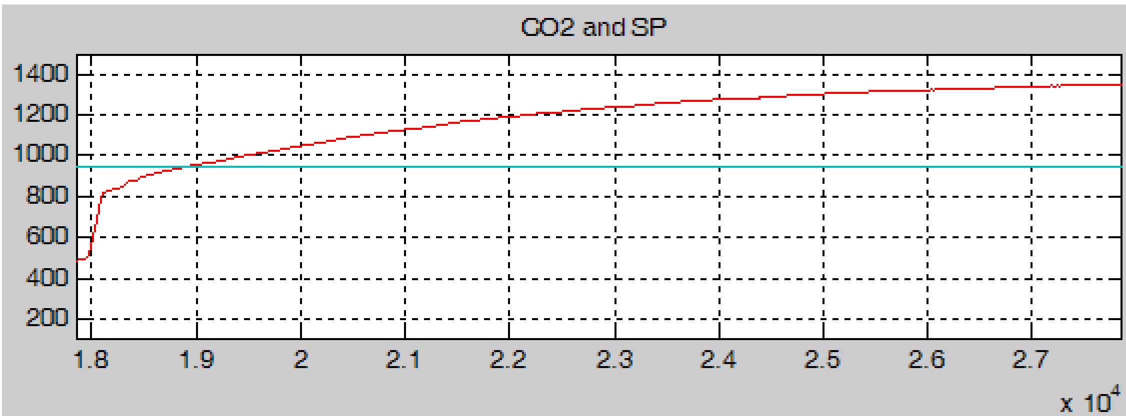
CO_2 should be steady before the test.

Change CO_2 Set Point and wait until the stabilisation.

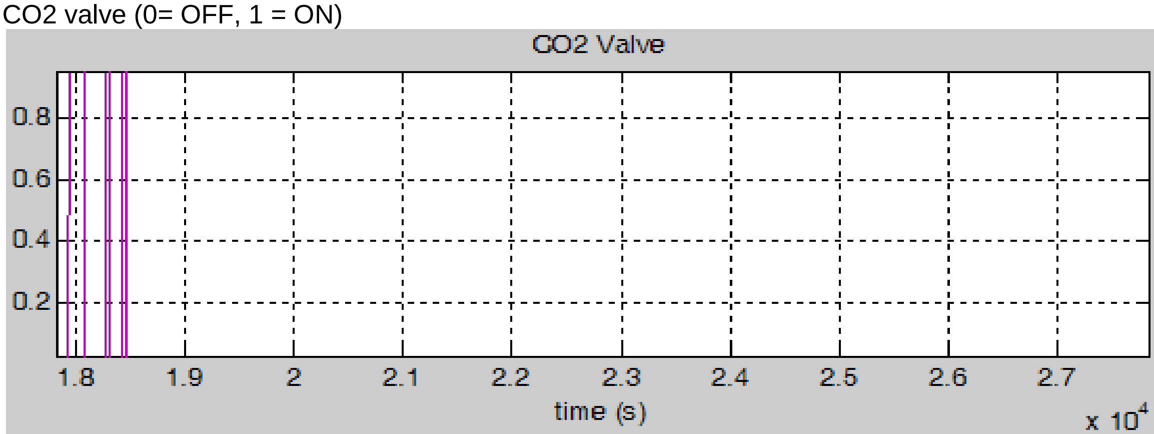
Seq Nb	Description	Required	Remarks	Status
1	(HMI) CO_2 Set Point = CO_2 Measurement Ex : CO_2 set point = 380 ppm			OK
2	(HMI) CO_2 Mode from OFF to AUTO			OK
3	Wait for stabilisation	CO_2 = CO_2 set point		
4	(HMI) Increase CO_2 to 1000 ppm		Set Point = 950 ppm	
5	Wait for Stabilisation	Indicate Time for Stabilisation	Very long stabilisation (2h45)	
6	(HMI) Increase CO_2 Set Point : + 100 ppm Ex : 1100 ppm		Not performed as CO2 was above 1100 ppm after stabilisation.	

7	Wait for Stabilisation	Indicate Time for Stabilisation	Non Applicable	

Hereafter CO2 measurement (red) and Set Point (blue) in ppm



CO2 valve (0= OFF, 1 = ON)



Remark :

- After stopping the CO_2 injection. CO_2 increases quite a lot. During 2h45.
- Behaviour will be different with crop as the plants are CO_2 consumer. Final tuning will be updated with crop tests.

13.4 T&RH Control Loop

These tests can be performed without and with crop

All variables and Set Points should be recorded

Remark : "Stabilisation" means T & RH should be stable.

13.4.1 Operating Conditions

Chamber Closed. Curtains closed	
Lights Off	
Irrigation Mode (HMI) in AUTO → GP_4106_01 is ON	
Air Blower Mode (HMI) in AUTO → Air Flow (FT_4111_01) around 20 m/s	
Ensure Cooling system is ON (TT_4412_13 between 8°C and 10°C)	
Ensure Heating system is ON (TT_4412_14 above 45°C)	
(HMI) Condensate level control in AUTO mode	

13.4.2 Variables to be recorded

All Temperatures and Set Points
Chilled Valve S3CV_4112_01
Hot Valve S3CV_4112_02

13.4.3 Test As-Run Procedure

Remark : depending on the startup conditions. The tests could be done either decreasing or increasing first the Relative Humidity. Or decreasing or increasing the Temperature.

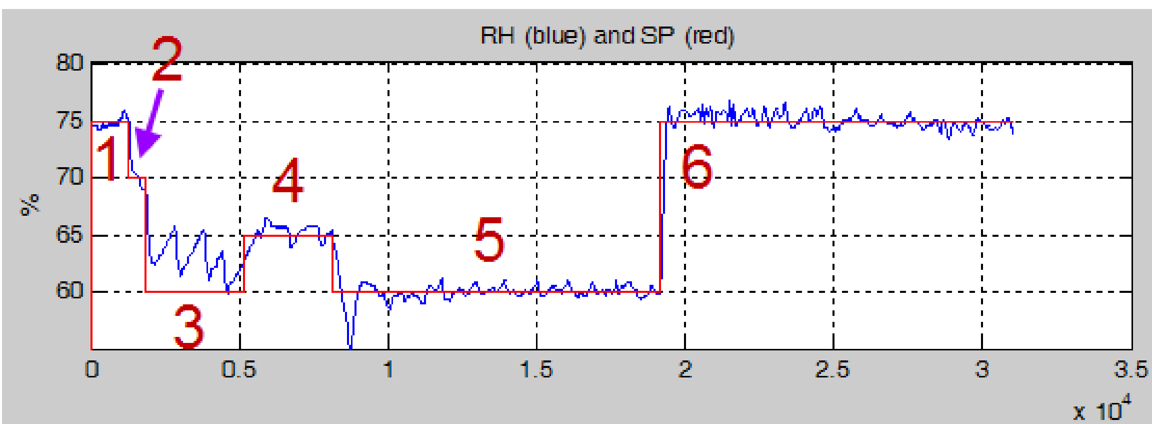
17.07.09 : the initial protocol has been adjusted to the operating conditions

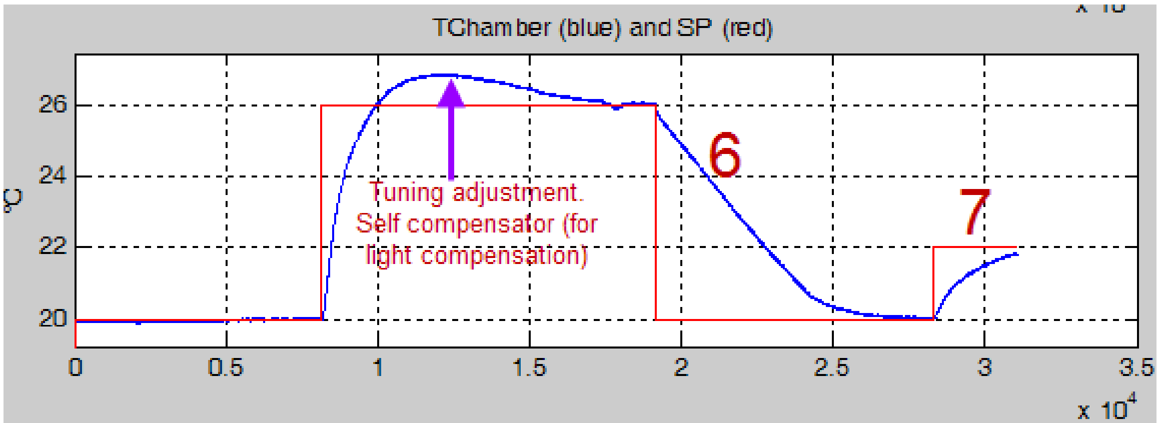
Seq Nb	Description	Required	Remarks	Status
1	(HMI) Temperature Set Point = Temperature Measurement		T Set Point = 20°C	OK
2	(HMI) Humidity Set Point = Humidity measurement		RH Set Point = 75 %	OK
3	(HMI) Temp. & Hum. Mode in AUTO mode			OK
4	Wait for stabilisation	T =T set point RH = RH set point	See **1**	OK
5	(HMI) Decrease Humidity to 70 %	RH set point = 70 %		
6	Wait for Stabilisation	Indicate Time for Stabilisation	See **2**	OK
7	(HMI) Decrease RH to 60 %			
8	Wait for Stabilisation	Indicate Time for Stabilisation	In this configuration. It is physically impossible to obtain 60 % → reincrease Set Point to 65 % See **3**	
9	(HMI) Increase RH to 65%			OK
10	Wait for stabilisation	Indicate Time for Stabilisation	See **4**	OK
15	(HMI) FAN Mode in AUTO (HMI) Light Mode in AUTO	Lights ON		OK
11	(HMI) Decrease RH set Point to 60 %			
13	(HMI) Increase T Set point from 20°C to 26°C		Lights ON and T SP = 26 °C and RH SP = 60 % at the same time	OK
14	Wait for stabilisation	Indicate Time for Stabilisation	RH overshoot : 10 % Temperature reaches the SP in 30 minutes Overshoot : 1 °C due to lights; Tuning was adjusted for compensating this	OK

			contribution. See **5**	
15	(HMI) FAN Mode in AUTO (HMI) Light Mode OFF	Lights OFF	Lights OFF and Set Point changes	
17	(HMI) Decrease Temperature to 20 °C			Ok
19	(HMI) Change RH Set Point to 70 %			Ok
20	Wait for stabilisation	Indicate Time for Stabilisation	1.5 h to decrease the temperature See **6**	OK
17	(HMI) Change Temperature Set Point to 22 °C			Ok
22	Wait for stabilisation	Indicate Time for Stabilisation	30mn to increase See **7**	OK

Remark :

- Excepted the non feasible change (point 3 in the graphs). The protocols demonstrate that it is feasible to control both T and RH
- These good results should be confirmed with crops.
- RH is controlled at +/- 1%
- Temperature is controlled with an accuracy less than 0.1 °C




TChamber (blue) and SP (red)
Tuning adjustment.
Self compensator (for
light compensation)
6
7
ºC
26
24
22
20
0
0.5
1
1.5
2
2.5
3
3.5
x 10^4

13.5 Conclusion

The closed loop tests demonstrated that :

- EC is controlled
- pH is controlled

- T & RH are controlled (in the limits of the physics possibilities between T and RH as there is no water addition)

About CO_2, a second test should be done to confirm the long time for stabilisation in the chamber. In presence of crops, it was not a problem as they were CO_2 consumers.

14. Overall conclusion

The results of Functional Testing of HPC1 after Argus Control System replacement by Schneider Hardware with Sherpa's control subroutines showed satisfactory operation of all HPC1 subsystems with the exception of air lock purge system functional testing which failed. However that problem was not connected with replacement of the control systems but with HPC1 design as the interior door was flexible and partially permeable.

Control of all environmental conditions in the chamber in general performed well during the crop test. However, like in the previous crop test with Argus controller, some deviation in day temperature and humidity control was observed. During the crop test with Argus PLC the control of humidity didn't perform well and it was supposed that it was partially related to insufficient control system tuning and insufficient stability of chilled water temperature. However, the results of crop test with Schneider PLC showed that fluctuations of day temperature and day relative humidity were not linked to utilities temperatures values but were connected with physical incompatibility between temperature and relative humidity when day temperature set point is 26°C and day relative humidity set point is higher than 60 %. Moreover, during the first 6 days of the test due to low plants transpiration day relative humidity can be well controlled only if it is set to 50% when day temperature set point is 26°C. Also, in order to obtain correct values on HPC room temperature it is necessary to change location of temperature sensor in future crop tests.

As a result of crop test after 11-days of HPC1 performance, lettuce plants had in average high biomass and green colour. However in comparison with previous crop test (Argus controller, TN 96.5) plants in module B had less biomass and some leaves of the plants grown in module B were yellowish that did not take place after the test with Argus controller. It was assumed that the possible reasons could be high air velocity in module B and low water flow. It was suggested to perform a test regarding water flow distribution per each spigot and to install at least one temperature and humidity sensor in the growth area of module B.

15. Comments

Functional Testing with Schneider Controller – As-run procedures, Test results and final Test report Comments

General comments

The TNs are rather comprehensive however we miss basically some evaluation of the results and overall conclusions eg comparison with results of functional tests performed in Guelph, comparison between results obtained with Argus and with Schneider, overall conclusion on the functional testing of the chamber
Overall conclusion is added in Section 14, including the comparison with results obtained with ARGUS system.

Some TNs and especially TN 96.5 are looking like compilation of inputs from several partners however without any link in between; some curves are even duplicated from one chapter to the other. The added-value of confronting different "views" (i.e control point of view, growing plant point of view...) of the chamber is missing. As a result the TNs look fuzzy and are very difficult to read and to use.
Confronting views foreseen more in last TNs (96.12 and 13).

Sometimes we do not understand the logic followed to fill in the as-run procedures, see detailed comments on each TN
OK, amended in each case.

There is a general mistake on EC unit, to be expressed in mS/cm or dS/m (these two units are equivalent)
OK, amended in each case.

Date and time in the as-run procedures are missing; in TN 96.5, the term ESA/UoG representative should be updated as discussed previously
OK, amended in each case.

The wording of the introduction, e.g. considered by ESA and SHERPA as a black box…. Should be rephrased.
OK, rephrased

A general conclusion is missing, although planned in TN 96.6-7
General conclusion is included in section 14

Some dates and times are missing in the test as-run procedures; please double check
Dates updated, sometimes the exact time was not recorded.

As for TN 96.5, it is very clear sometimes why the column measured/calculated is not filled in; please double check
OK, updated.

Detailed comments

Page/paragraph	Comment
8	I think you cannot conclude a test as passed if if it was not performed or not applicable, don't you think? Agreed. Amended in the document.
12	Please clarify why a test is not applicable when appropriate The tests non applicable were the ones not related to control, and already performed in the HPC during the previous fuctional tests campaign with ARGUS controller, so not necessary to be repeated. Clarified in the document.
16	Failed instead of not performed in Seq nb. 3 and fol.? Agreed. Amended in the document.
18/Section 3.13	Please remove 8&10 from the table Done
22 and fol.	Please make a ref to the deviation paragraph otherwise a lot of seq. should be concluded as failed instead of passed. Document amended accordingly.
25 Seq 24	Values measured are still under the new req (i.e. 140); then the test is "failed", isn't it? Link made to the deviations table
25	Comment by MPP: further explanation is added in the conclusion of lighting subsystem regarding loft temperature test
27	Please justify the decision to change the requirement? Any impact on the culture? The justification is given in the document

39 Seq 3	Should be anoted as failed In fact, considering the potential error of the gas analyser (1% full scale), 30 ppm of deviation can be accepted; referenced to the deviation accordingly.
45	Please include in the procedure a reference to the deviation Document amended accordingly.
51	Please include a ref to the deviation when appropriate Document amended accordingly.
55 Seq 7	Failed would be maybe more relevant? Any action decided? Amended in the table. The offset should be corrected (text rephrased and included in the conclusions)
61 and fol	Please reorganize this paragraph; without outline/numbering, it is extremely difficult to follow; could be wise to merge the conclusions in one paragraph and address there the various aspects instead of having several conclusions paragraphs. Section reorganised
62/Section 12.5	Again pH 5.9? In the crop test with Schneider controller pH set point was 5.9
61/Section 12.8	Temperature and humidity deviations took place: please explain and clarify; some errors of HMI: please explain and clarify; impossibility to reach 26oc and 75% RH: please link to physical causes and comment on this impossibility, is it critical?... All explanations are given in the document; comment on the criticality of impossibility to reach 26oc and 75% RH is given in the conclusion, page 67
63	Do you mean that values RECORDED for ambient temp are changing with HPC1 temp but that this is an artefact because of the location of the sensor, i.e.values recorded are wrong? Please clarify and reword. Explained in the text: that artefact was caused by the location of the sensor, which was placed in a zone where the lights loft air was exhausted and the values recorded were wrong.
64	Why is figure 2 covering this reduced period of time only?

	This figure covers the same period of time as it was done in TN 96.5 for the crop test with Argus controller
65	Is figure 3 representative of every day? Please precise Yes, it is representative of every day under nominal conditions
66	Can you explain the presence and intensity of unusual peaks? Transplanting at the beginning? Harvesting of 20 crops after 7 days? In that case can you comment on the peak at 2500 ppm (seems to be a very hig value). Explanation of events given in the text
67	Fig 5: can you comment on the peak at day 7? Commented in the text
67/conclusions	Can you please refer to graphs or illustrate your conclusions? Text amended accordingly
68 and fol.	Comments on the crop test are similar to the one in TN 96.5; it is sometimes very difficult to follow if you do not precisely remember the chronology of the test, i.e. 3 phases etc…Even in 12.5 you mention the test will last 7 days and you pursue over 11 days. Please update.Raw data in annex would be appreciated; when applicable 3D graphs would ease the understanding of the text. Numbers of figures in the text are not consistent with the figures numbering Text amended, raw data appended (Appendix 2), 3D graphs provided and numbering amended
78	Inhibition: can we really use this term of inhibition? Wording amended: "plant production decrease"
78	As for TN 96.5, please clarify if the nutrient solution has been renewed or not, detail your sampling strategy….How can you explain the very high dispersion over the three samples of nutrient solution? The information on solution renewal is given in paragraph 12.3 of this document; explanations are added
79	Can you illustrate the last sentences above the table, e.g. with comparative graphs. Graph included (Figure 18)
79	"Treatment 1"is not so clear to me: did you make your transplanting after 14 days or 18 days? Then what about the remaining seedlings? As for TN 96.5, a chronology of the test would help the reviewer

	Explanation is added to the document
80	Please clarify the sampling strategy Clarified in the document
80/table 5	Obtained: do you mean uptaken? there is a set expression in plant physiology when it comes to those elements (C, H), "obtained from water", etc.
80	In the last paragraph: concentration of minerals ; do you mean quantities? If not then clarify the meaning of the sentence Text amended
81/table 6	Why do you make the calculations for 165 seedlings, whereas you do it only respectively for 20 and 80 plants for the other treatments? There were 2 Rockwool flats for seedlings cultivation, each one for 100 seeds. From 200 sown seeds only 165 seedlings had grown. Since each flat was irrigated with certain quantity of nutrient solution, it was possible to calculate how much of nutrients were used for growing 165 seedlings and how much nutrients were accumulated in those seedlings. The same calculations were done for 20 and 80 plants, since there was data on plants and nutrient solution composition at different growth phases.
82/table 7	Please clarify how you obtained the data of this table As it was explained in the previous answer, it was known how much of nutrient solution was used for whole period of seedlings growth, the composition of the solution was known, the nutrients content in the seedlings leaves was analysed. By subtraction of nutrients quantites accumulated in the seedlings leaves from nutrients quantities applied with nutrient solution it was calculated how much nutrients left in rockwool, roots and trays
82/conclusions	I am surprised not to see anything about potential micorbiological problems; nothing is mentioned about potential preparation of the HPC between two cultures, e.g. cleaning, disinfection..; can you complement/ clarify? At this crop test no cleaning and disinfection was performed, no potential micorbiological problems were detected
83/84	Please update EC unit Updated
84	Can you describe what is on the graph? Can you precise the legends?

	One graph was missing (EC and Set point). Added. Legends updated
86	Legends of the graphs? Updated
87	"Very long stabilisation": can you be more precise? Updated
88	Why is seq 7 not filled in?can we have the record of Co2 increase? Any conclusion to be drawn? Graph added. Updated. This test demonstrates that control of CO2 is feasible. CO2 tuning will be updated with crops.
92	"Physics possibilities: do you mean chamber design versus operating conditions?Pleae rephrase the last sentence "it was not be". Did you or not perform this test with crops, ie. 26oC and 75% RH? As there was no water addition there are limits between T and RH, for instance 60% and 20°C was not reachable. Results were confirmed later with crops. Tests with crops were performed during crop tests. Not especially 26°C/75%. Sentence amended.

16. APPENDIX 1 – chronology of events for seedlings establishment

1) **6.08 Thursday**

Sterilization of 2 flats of rockwool small cubes - Grodan AO 36/40 6/15W with autoclave and seeds with 5% bleach (TN 96.3). Sowing of 196 seeds into 2 Rockwool sheets. Photographing. Placement of the trays with Rockwool sheets into the HPC1. Lighting was enabled. 2 lamps per each module were on (1HPS and 1 MH). PAR intensity in module C (where trays sown lettuce were located) was 232 µmol*m^{-2}*s^{-}. Temperature set point for the day time was 20°C, but actual temperature was 23.3°C. Night temperature set point was 20°C. Humidity set point was 70%, but was impossible to reach as temperature was growing, so was changed to 40%.

2) **7.08 Friday**

Measurement of irrigation solution (½ strength nutrient solution) pH, it´s 5.92. More than 60 percent emergence could be observed, the plastic lid of each tray was removed. Watering of each tray with 500 mL of seedlings solution. Photographing.

3) **8.08 Saturday**

No operations.

4) **9.08 Sunday**

Temperature in HPC1 was 30ºC and humidity was 85% since temperature control was off; error on hot water supply. At 18:40 both trays were taken out of HPC1, photographing. Emergence of more than 70% of seedlings. Watering of both trays with 800 mL of seedling solution each. Both trays were put back into the chamber (module C). At 18:50 lights are on, temperature and humidity control are on, set points: t=20ºC. %Rh=70% (actual temperature and humidity at that time: t=30.5ºC, %Rh=75.9%). At 19:02 humidity set point was changed to 60%, at 19:04 changed to 50%, at 19:14 to 40% in order to decrease temperature and maintain it at 20ºC. At 19:34 t=25ºC, %Rh=44.1%

5) **10.08 Monday**

At 9:45 all parameters were nominal on HPC1. Both trays were humid, no watering. Photographing. More than 85% of seedlings were visible. At 15:30 power cut off, temperature and humidity control were off. Reset. At 16:09 t=21.9ºC, %Rh=52.4% in HPC1. At 17:00 power cut off in SAI 9.1. HMI was disabled and not possible to enable. At 18:00 temperature in the chamber (measured with thermometer) was 26ºC. Both trays were taken out of the chamber, covered with plastic lid and left in HPC room at ambient conditions.

6) **11.08 Tuesday**

At 8:40 photographing of the seedlings. about 90% of seedlings were observed. Problems with activation of HPC1 control system. Only after HPC1 PLC UPS turning off and on control was activated. Night for the plants. At 18:15 each tray was watered with 400 mL of seedling solution. t=20.6ºC, %Rh=56.5%

7) **12.08 Wednesday**

Photographing. Measurement of the solution pH, it´s 5.97. Watering of each Rockwool sheet with 400 mL of solution. At 12:05 in order to finish the compensation for shorter lighting period on 10.08.09, the day cycle was modified: from 10:30 12.08.09 till 5:00 13.09.09.

8) **13.08 Thursday**
Photographing. Irrigation of both trays, 600 mL per each tray.

9) **14.08 Friday**
Photographing. Watering of each Rockwool sheet with 900 mL of nutrient solution. At 9:45 3d lamp in each module of the chamber was switched on. Day temperature set point: 26.0°C. %Rh set point: 70%. At 10:42 enabled CO_2 control. CO_2 setpoint 1000 ppm.
At 15:25 humidity set point was set down to 40% as temperature was 31.0°C.

10)**15.08 Saturday**

At 12:09 %Rh=81.3%, t=32.6°C. At 12:25 disabling of Ramp Sa in order to decrease temperature. The chamber was opened. each tray was irrigated with 400 mL of seedling solution. Temperature didn’t decrease. Problems with software (errors appeared). At 12:30 restarting of software. Light, humidity and temperature modes were enabled in auto. Decrease of humidity and temperature were observed (%Rh set point was 40%,. temperature set point was 26°C).

11) **16.08 Sunday**
Chamber was closed, control system was enabled.

12) **17.08 Monday**
At 8:20 one string of HPS lamps (ramp Sa) was operating although there shouldn’t be illumination in the chamber from 2:30 until 10:30 (according to set points). Lights were disabled. At 9:36 CO_2 control was disabled. The chamber was opened. Photographing of the plants. Watering of the plants with the solution, 900 mL per each tray. Germination in the right tray (next to spigots) was 79.4%, in the left one – 86.7%.
At 9:49 the chamber was closed and CO_2 control was enabled. At 11:44 , t=29.9ºC, %Rh=81.4% and control of temperature and humidity was off. At 11:45 control of temperature and humidity was enabled in auto mode (%Rh set point was 40%. temperature set point was 26°C).

13) **18.08 Tuesday**
At 8:05 t=20.0ºC, %Rh=70.1% (night in HPC1). At 10:14 CO_2 control was disabled. The chamber was opened. Photographing of the plants. No irrigation as medium was humid. At 10:21 the chamber was closed and CO_2 control was enabled. At 11:27 it was observed that temperature and humidity control was off and t=28.2ºC, %. Rh=82.97%. Problems when there was transition from night to day. Control was enabled again.

14) **19.08 Wednesday**

At 9:44 CO_2 control was disabled, the chamber was opened. Check of pH of seedling solution, it’s 5.88. Watering of the plants with the solution. 1 L per each tray. Photographing. The chamber was closed and CO_2 control was enabled. At 11:29 it was observed that temperature and humidity control was off and t=29.4ºC, % Rh=82.0%. It seemed that control went off at 10:40 when temperature was 25.07 ºC and humidity was 46.98%. Enabled again.

15) **20.08 Thursday**

At 9:30 CO_2 control was disabled, the chamber was opened. Watering of the plants with the solution. 1 L per each tray. Photographing. At 9:42 the chamber was closed and CO_2 control was enabled. At 11:05 temperature and humidity control was switched off, reset to on. and t=27.1ºC, %Rh=76.5%.

16) **21.08 Friday**

Start up of crop test

17. APPENDIX 2 – Raw data on lettuce weight, elemental compositions and minerals concentration in the nutrient solution

Table 1. Fresh and dry weight of lettuce leaves, harvested after 7 days of closure (28.08.2009)

# of tray	# of plant	Fresh weight, g	# of sample for lyophilization	Dry weight, g
1	3	10.61	1	2.7
2	3	13.42		
3	3	14.2		
4	3	13.36	2	2.8
5	3	13.96		
6	3	13.09		
7	3	15.92	3	2.4
8	3	10.23		
9	3	10.62		
10	3	10.67	4	2
11	3	8.1		
12	3	12.22		
13	3	5.99	5	1.9
14	3	12.3		
15	3	12.77		
16	3	9	6	2.8
17	3	11.92		
18	3	14.31		
19	3	14.6	7	1.8
20	3	8.51		

Table 2. Dry weight of lettuce leaves after lyophilization, harvested after 11 days of closure (1.09.2009)

# of tray	# of plant	# of sample for lyophilization	Dry weight, g
1	2	1	4
2	4		
3	2		
4	4	2	9.7
5	2		
6	4		
7	2	3	5.4
8	4		
9	2		
10	4	4	9
11	2		
12	4		
13	2	5	6.2
14	4		
15	2		
16	4	6	9.2
17	2		
18	4		
19	2	7	5.6
20	4		

Table 3. Fresh and dry weight of lettuce leaves after 11 days of closure (harvested on 1.09.2009)

# of tray	# of plant	Fresh weight, g	Dry weight, g
1	1	37.9	1.43
	2	46.4	
	4	46.16	1.71
	5	41.29	1.99
2	1	42.45	1.96
	2	54.79	2.82
	4	30.92	
	5	56.03	1.73
3	1	38.49	2.02
	2	40.42	
	4	42.98	1.91
	5	59.36	3.43
4	1	39.4	2.06
	2	49.61	2.73
	4	55.2	
	5	47.39	1.47
5	1	41.62	1.75
	2	48.9	
	4	55.47	2.66
	5	54	2.86
6	1	32.48	1.06
	2	43.02	1.96
	4	43.41	
	5	58.57	2.54
7	1	45.33	2.07
	2	37.08	

	4	40.81	1.65
	5	40.44	1.73
8	1	36.33	1.36
	2	36.49	1.65
	4	42.09	
	5	42.53	1.9
9	1	6.52	0.42
	2	6.96	
	4	42.01	2.03
	5	38.13	1.34
10	1	35.1	1.11
	2	41.12	1.77
	4	34.34	
	5	40.05	2.05
11	1	36.25	1.55
	2	33.73	
	4	37.25	1.26
	5	38.98	1.85
12	1	33.29	1.14
	2	36.19	1.31
	4	39.95	
	5	30.92	1.44
13	1	28.59	1.59
	2	26.51	
	4	37.43	2.1
	5	29.05	1.5
14	1	29.62	1.6
	2	37.77	2.02
	4	37.31	
	5	29.09	1.56
15	1	31.85	1.26
	2	35.16	

	4	40.17	1.56
	5	43.77	2.33
16	1	35.88	1.66
	2	44.33	1.81
	4	50.65	
	5	43.16	1.3
17	1	36.19	1.59
	2	43.76	
	4	57.29	2.66
	5	38.82	1.4
18	1	55.09	2.47
	2	57.38	2.99
	4	59.09	
	5	18.43	2.52
19	1	41.52	2.32
	2	48.53	
	4	44.45	2.02
	5	44.19	2.23
20	1	45.09	1.95
	2	55.06	2.33
	4	48.23	
	5	51.83	2.03

Table 4. Concentration of minerals and trace elements in the nutrient solution during 11 days of closure (mg/L)

Date, # of samples	Ca	Mg	K	Na	Cu	Mn	B	Zn	Mo	Fe	P	S	N-NH_4
24.08.2009, sample #1	250	90	769	10	0.19	1.02	0.78	0.94	0.15	9.2	146	234	135
24.08.2009, sample #2	208	35	312	8.5	0.072	0.39	0.30	0.41	0.062	7.5	64	93	74
24.08.2009, sample #3	210	35	310	7.6	0.071	0.38	0.29	0.40	0.057	7.6	63	91	73
28.08.2009, sample #1	219	36	321	7.9	0.076	0.40	0.30	0.40	0.057	8.0	62	94	68
28.08.2009, sample #2	216	35	316	7.8	0.073	0.39	0.29	0.39	0.051	7.8	61	93	64
28.08.2009, sample #3	215	35	313	7.7	0.073	0.39	0.29	0.39	0.051	7.8	61	93	68
01.09.2009, sample #1	238	38	334	11	0.077	0.43	0.32	0.38	< 0.04	8.7	57	98	49
01.09.2009, sample #2	242	38	341	38	0.087	0.43	0.37	0.43	0.04	8.9	57	100	42
01.09.2009, sample #3	241	38	339	8.6	0.076	0.43	0.31	0.37	< 0.04	8.8	56	98	48

Table 5. Mineral composition of lettuce shoot, harvested at different phases of vegetation

Treatment	# of samples[4]	Mineral and elemental content (% dw)														
		Ca	Mg	K	P	S	C	H	N	Fe	B	Zn	Mo	Mn	Cu	Na
[1]Treatment 1	1	1.69	0.404	6.88	1.12	0.47	35.44	4.99	6.84	0.039	0.003	0.009	0.0002	0.010	0.002	0.097
[2]Treatment 2	1	1.01	0.289	5.79	0.74	0.40	39.46	5.66	5.55	0.016	0.003	0.005	0.0003	0.005	0.001	0.028
	2	1.16	0.326	5.80	0.76	0.43	38.34	5.50	5.52	0.050	0.003	0.006	0.0003	0.008	0.006	0.039
	3	1.06	0.307	6.14	0.81	0.43	38.29	5.40	5.58	0.013	0.003	0.006	0.0003	0.005	0.001	0.030
	4	1.15	0.337	6.33	0.86	0.45	37.84	5.40	5.80	0.016	0.003	0.007	0.0003	0.006	0.001	0.031
	5	1.24	0.346	6.42	0.84	0.47	38.25	5.43	5.86	0.016	0.003	0.006	0.0003	0.006	0.002	0.031
	6	1.10	0.287	6.28	0.78	0.45	40.23	5.49	5.59	0.013	0.003	0.005	0.0002	0.006	0.001	0.028
	7	1.01	0.283	6.25	0.78	0.40	40.44	5.59	5.83	0.012	0.003	0.006	0.0003	0.005	0.001	0.025
[3]Treatment 3	1	0.94	0.273	5.65	0.81	0.43	40.40	5.66	5.65	0.013	0.003	0.005	0.0002	0.005	0.002	0.027
	2	1.05	0.280	5.86	0.83	0.46	38.24	5.39	5.69	0.011	0.003	0.006	0.0003	0.006	0.001	0.028
	3	1.05	0.281	5.71	0.78	0.43	38.87	5.41	5.79	0.015	0.003	0.006	0.0002	0.006	0.002	0.028
	4	1.07	0.292	5.85	0.85	0.45	39.09	5.51	6.00	0.019	0.003	0.007	0.0002	0.006	0.006	0.031
	5	1.03	0.279	5.72	0.80	0.43	40.37	5.39	5.94	0.011	0.003	0.006	0.0002	0.006	0.001	0.028
	6	0.99	0.255	5.81	0.79	0.40	40.25	5.44	5.92	0.012	0.003	0.006	0.0002	0.006	0.001	0.027
	7	0.97	0.265	6.07	0.83	0.43	39.54	5.34	6.07	0.015	0.003	0.006	0.0003	0.006	0.003	0.026

[1]- seedlings of lettuce (shoots) in age of 18 days after seeds sowing, the rest of the seedlings (totaled 65) after crop test start up

[2]- lettuce shoot, located in the central raw along HPC1 (plant #3), harvested after 7 days of crop test

[3] - lettuce shoot, plant #2 (samples were taken from trays #1,3,5,7,9,11,13,15,17,19) and plant #4 (samples were taken from trays #2,4,6,8,10,12,14,16,18, 20), harvested after 11 days of crop test

[4] - # of samples corresponds to # of sample for lyophilization (see tables 1 and 2 of Appendix 2)

Table 6. Content of elements, obtained from CO_2 and water, in lettuce shoots, harvested at different phases of vegetation (% dw)

Treatment	# of samples[4]	# of replications	C	H
[1]Treatment 1	1	1	35.43	4.99
		2	35.49	5.01
		3	35.40	4.96
[2]Treatment 2	1	1	39.13	5.63
		2	39.44	5.60
		3	39.82	5.74
	2	1	38.76	5.50
		2	38.79	5.66
		3	37.45	5.34
	3	1	38.50	5.44
		2	38.87	5.50
		3	37.51	5.26
	4	1	37.74	5.33
		2	38.21	5.45
		3	37.56	5.43
	5	1	38.43	5.46
		2	38.37	5.47
		3	37.96	5.38
	6	1	40.38	5.49
		2	40.28	5.52
		3	40.03	5.47
	7	1	40.15	5.55
		2	40.22	5.50
		3	40.95	5.72
[3]Treatment 3	1	1	40.83	5.69
		2	40.17	5.68
		3	40.21	5.62
	2	1	38.05	5.34

		2	38.36	5.38
		3	38.32	5.45
	3	1	39.30	5.55
		2	38.84	5.34
		3	38.48	5.33
	4	1	38.91	5.46
		2	39.29	5.53
		3	39.08	5.53
	5	1	40.84	5.45
		2	39.99	5.35
		3	40.28	5.36
	6	1	40.19	5.43
		2	40.14	5.43
		3	40.41	5.48
	7	1	39.78	5.36
		2	39.37	5.29
		3	39.47	5.38

[1]- seedlings of lettuce (shoots) in age of 18 days after seeds sowing, the rest of the seedlings (totaled 65) after crop test start up

[2]- lettuce shoot, located in the central raw along HPC1 (plant #3), harvested after 7 days of crop test

[3] - lettuce shoot, plant #2 (samples were taken from trays #1,3,5,7,9,11,13,15,17,19) and plant #4 (samples were taken from trays #2,4,6,8,10,12,14,16,18, 20), harvested after 11 days of crop test

[4] - # of samples corresponds to # of sample for lyophilization (see tables 1 and 2 of Appendix 2)