MODULAR AGRICULTURAL PRODUCTION SYSTEM (MAPS)

Dr. Krishna Kumar Sugumaran

Associate Research Scientist

Desert Agriculture and Ecosystems Program

Environment and Life Sciences Research Center

KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH

P.O. BOX: 24885,

13109 SAFAT, KUWAIT.

MAPS Prototype – Purely a Research Tool

MAPS is a powerful research tool which enables complete control of the abiotic and biotic factors influencing plant growth and development.

Specific Objectives:

- Customized light recipes
- Customized Nutrient Recipes

- for selective crop production.

General Objectives:

- Economics
- Secondary Metabolites
- Ethical aspects
- Genetic modifications

- in long term research strategy.


ARGUS
IO MODULE
ARGUS
IO MODULE

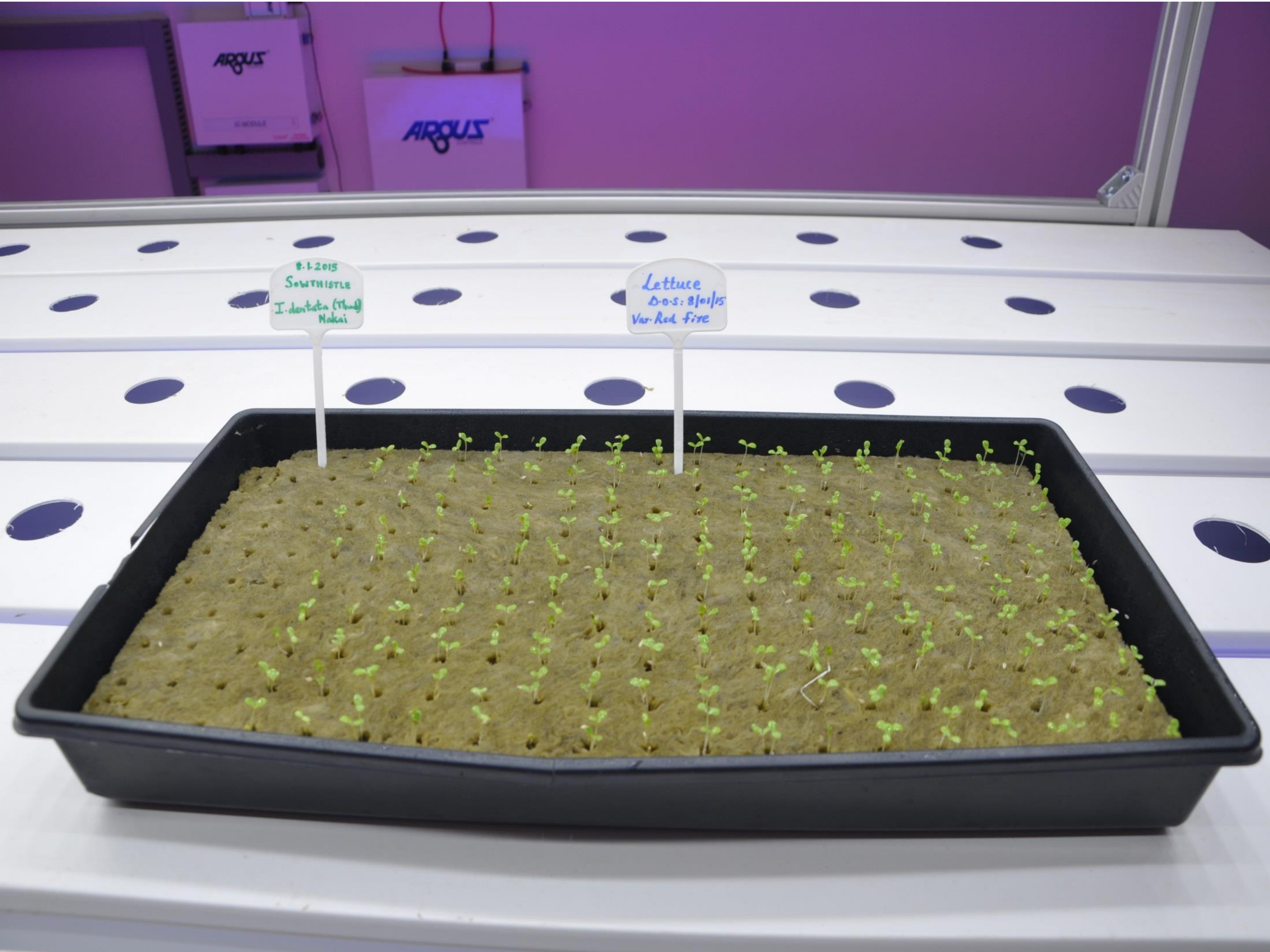

CAUTION: PLEASE DO NOT LEAN
Please Donot Touch
ARGUS


CAUTION: Please do not lean


Lactuca Sativa cv. New Red Fire
Blue LED Light
White LED Light
Red LED Light
LIGHT QUALITY TREATMENT

MODULAR AGRICULTURAL PRODUCTION SYSTEM (MAPS)

- Collaborative innovation of **KISR** and **University of Guelph, Canada**.
- Modular plant production system using **top-notch LED lighting technology** and **hydroponics**.
- Based on **NASA space research center technology concept** for **Life on Space**.
- **Unique and first of its kind** in the global map of agricultural research.
- Completely controlled growing environment for **high quality designer plants**.
- Capable of **remotely controlling** the **system environmental parameters.**
- **Remotely accessible Argus Control system** for real time data acquisition and crop management.
- Possibility to **hygienically** produce **very high quality designer plants.**
- A completely closed **high density production system** with **excellent research potential**.
- Consumer face produce under **hygienic plant production protocols**.
- Best suited for **urban scenarios** and **plant factory systems**.
- Initial experimental crop **LETTUCE -** *Lactuca sativa* cv. “New Red Fire”


ARGUS
ARGUS
8.1.2015
SOWTHISTLE
I. dentata
Nakai
Lettuce
D-O-S: 8/01/15
Var. Red fire


ARGUS


ARGUS


CAUTION: Please do not lean

Plant Nutrition and Experimental Design in MAPS

Hydroponics – Growing Plants in Water

Hydro = Water + Ponos = Labor

The science was in practice as early as 1800s – Hanging gardens of Babylon and Floating gardens in Mexico.

Advantage:

- Complete control of plant nutrition

Disadvantages:

- The reaction of plants to good or poor nutrition is unbelievably fast.
- Requires careful attention to details.

Applications of Hydroponics were Predicted Way Back

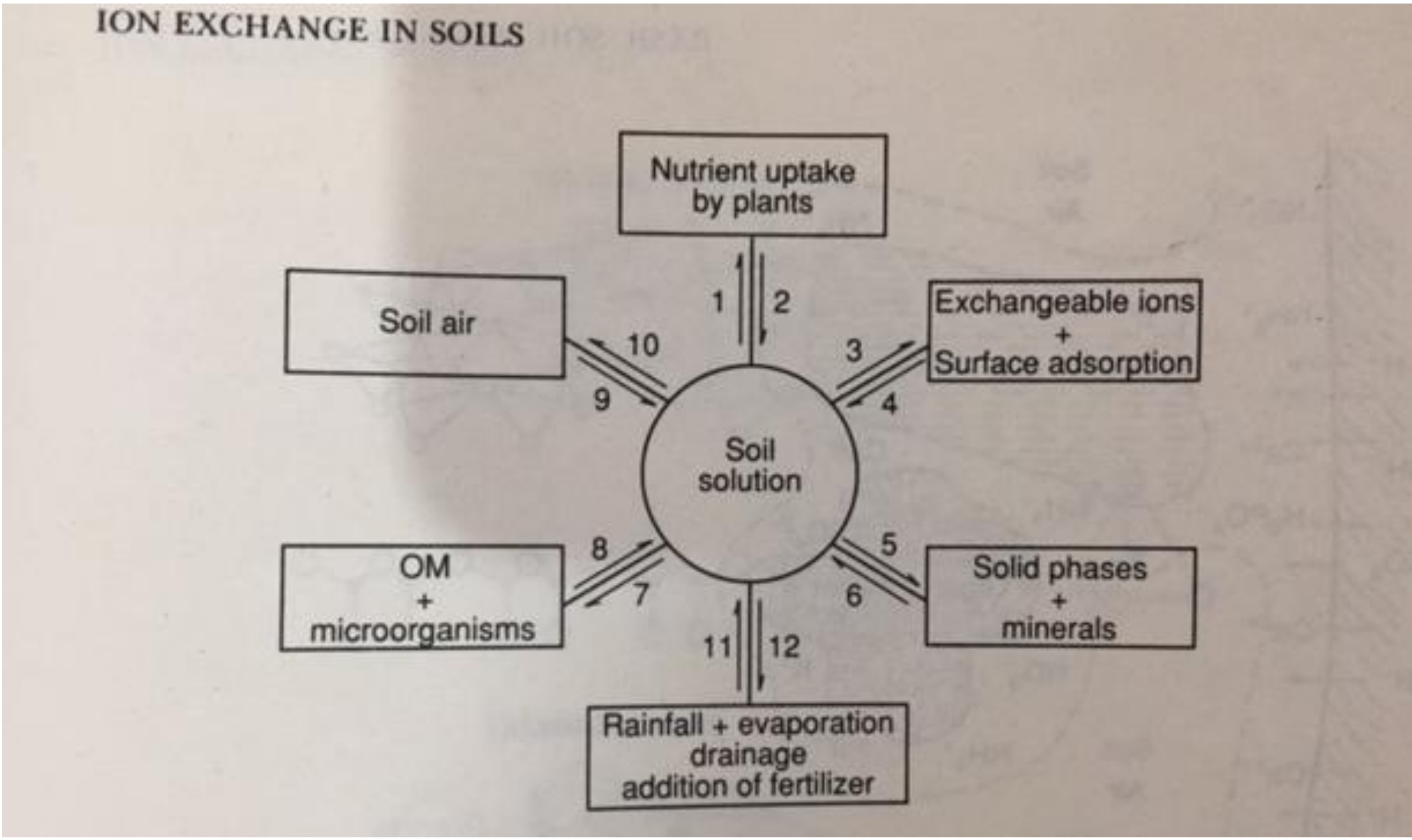
- Hydroponic growing in desert areas of the world and in areas such as polar regions or other in-hospitable regions will become important for providing food and/ or mechanism for waste recycling (Jensen and Tern 1971, Budenheim et al., 1995).

- Hydroponics for space applications – providing a means of purifying water, maintaining a balance between oxygen and carbon dioxide in space compartments, and supplying food for astronauts (Knight, 1989; Schwartzkopf, 1990; Tibbittis, 1991; Brooks, 1992).

All Agriculture Involves Hydroponics

- Scientifically speaking, at large; plant growth in all rooting media - including soil – is hydroponic, since the elements absorbed by plant roots must be in a water based solution.
- The concentration and movement of the elements within this solution depend on the nature of the surrounding medium.
- The complexity of the chemistry of nutrient solution is significantly simplified when the support medium shifts from soil – inert medium – medium-less system.

Relationships between the Various Components of the Dynamic Soil System



Systems of Hydroponic Culture

Medium-less Hydroponics

- Nutrient Film Technique (NFT)
- Aeroponics
- Aerated Standing Nutrient Solution

Medium Hydroponics

- Closed Insulated Pallet System (CIPS)
- Ebb-and-Flow Nutrient Solution System
- Bag or Pot Drip/ Pass-through Nutrient Solution System
- Rockwool Slab Drip Nutrient Solution System
- Vertigrow System
- Growbox system

Medium-less (True) Hydroponics

Medium Hydroponic Culture Systems

Facts about Nutrient Uptake in Plants

- Takes place in the form of ions
- Plant roots are capable of selective absorption of ions.
- Ion uptake by roots does occur across a considerable concentration gradient.
- Absorption of ions by roots require energy generated by cell metabolism.

Process of Nutrient Uptake in Plants

Passive Absorption

- Nutrient ions are carried along with water taken into the roots (**Mass flow**).
- As the amount of water absorbed through roots increases, the amount of ions also increase despite the existence of a highly selective uptake regulation mechanism.
- Controlling factors are the amount of water moving into the plants, the concentration of ions in water, and the size of the root system.

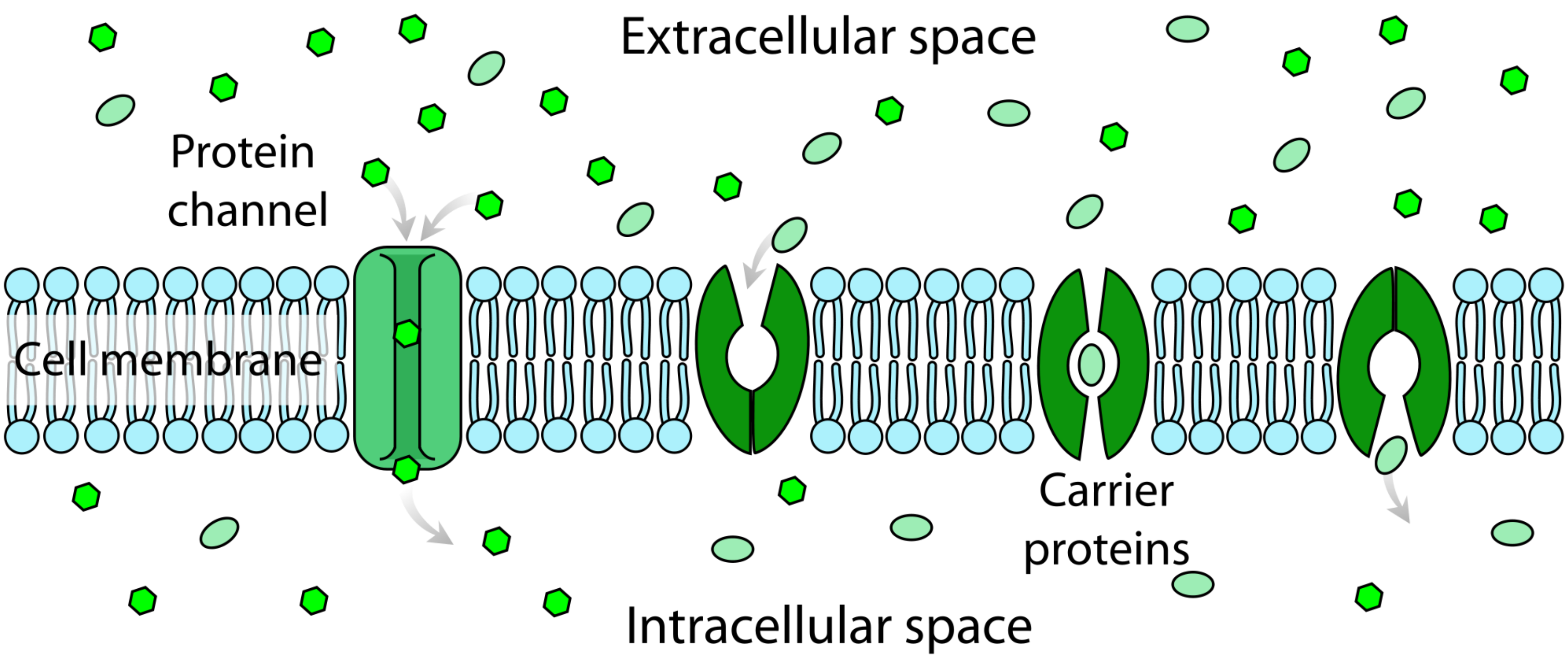
(Amino acids, simple proteins, K^+, $NO3^-$ and Cl^-)

Active Absorption

- The process involved is the **transporting of ions** across the cell membrane.
- A nutrient ion may be complexed with some substances (**ion-carrier complex**/ **transport protein**) and then **carried across** the cell against the concentration gradient.
- A carrier must be present and energy should be expended.
- Another theory explaining the process is the function of **ion pumps** – rather than specific carriers.

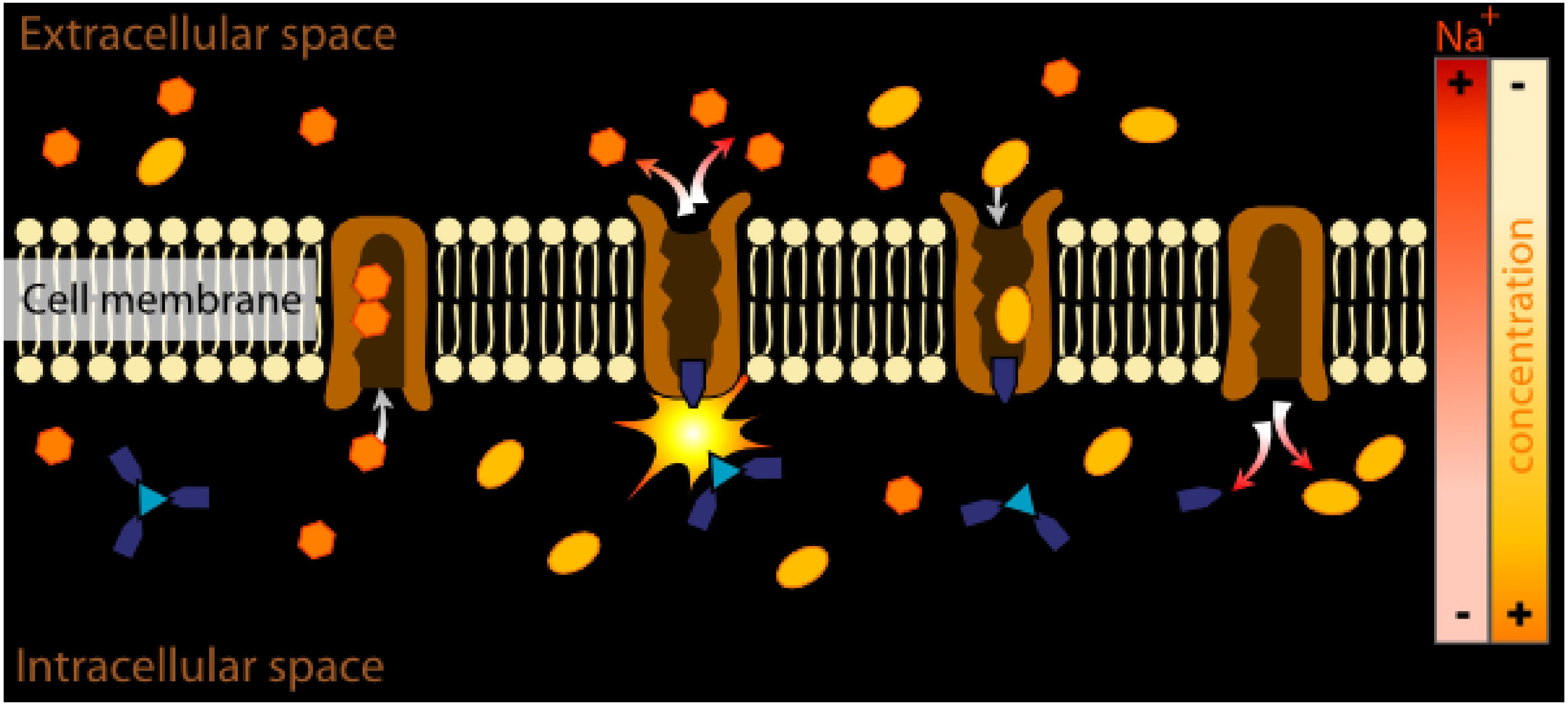
Nutrient Uptake in Plants

Passive Absorption   Active Absorption



Sodium – Potassium Pump

The sodium-potassium pump uses energy derived from ATP to exchange sodium for potassium ions across the membrane.



To Start with….

Clean the internal and inaccessible surfaces of the hydroponics system using the following protocol

- Empty the main nutrient reservoir and fill completely with a 0.5% bleach solution. (Note: 10 ppm ozone solution is the preferred method).
- Run the NDS system with plant troughs in all positions for a period of 24 hours.

-- Stop here if using aqueous ozone for disinfection –

- Drain the NDS reservoir and fill with clean water or nutrient solution as appropriate for proceeding experiments.

--If bleach is used, complete the following steps -

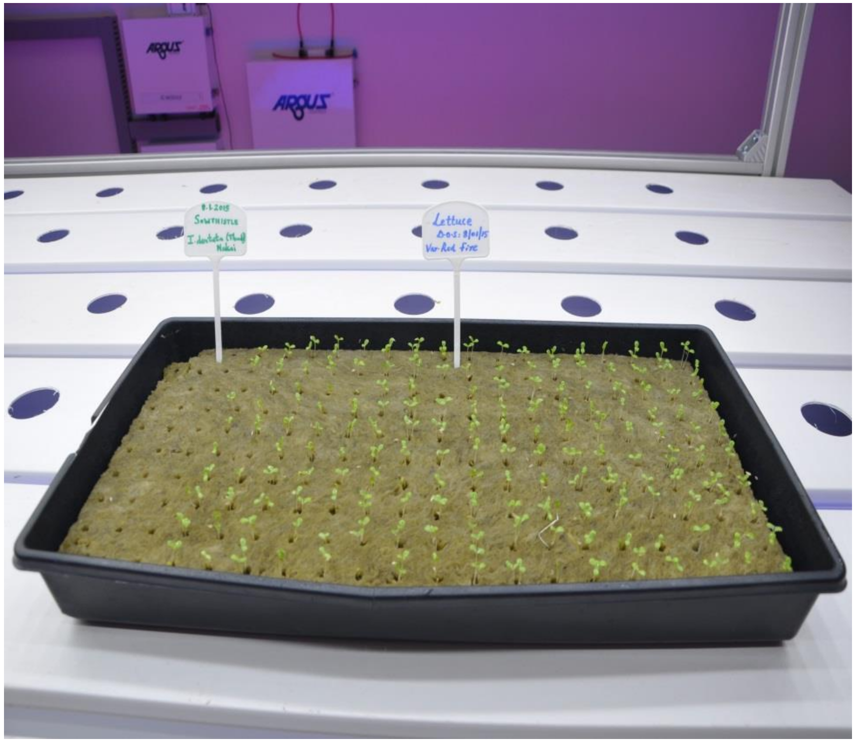
- Run the NDS system for up to 24 hours.
- Drain the NDS system and fill with clean water.
- Run the NDS system for 6 hours.
- Drain the NDS system and fill with clean water.
- Run the NDS system for 1 hour.
- Drain the NDS system and fill with clean water or nutrient solution as appropriate for proceeding experiments.

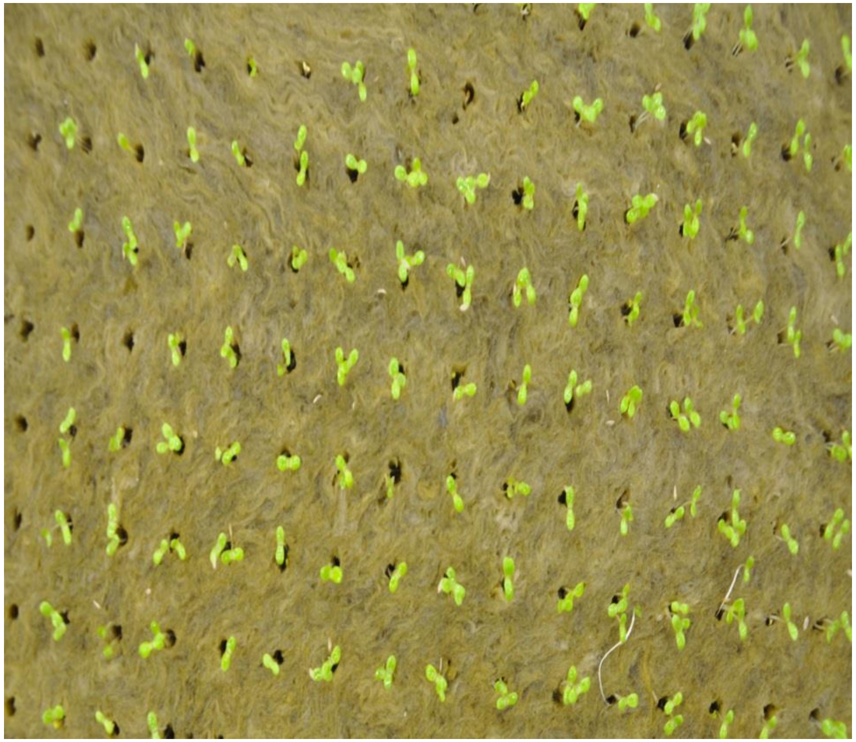
Sowing, Germination and Emergence

Irrigation with Fresh water

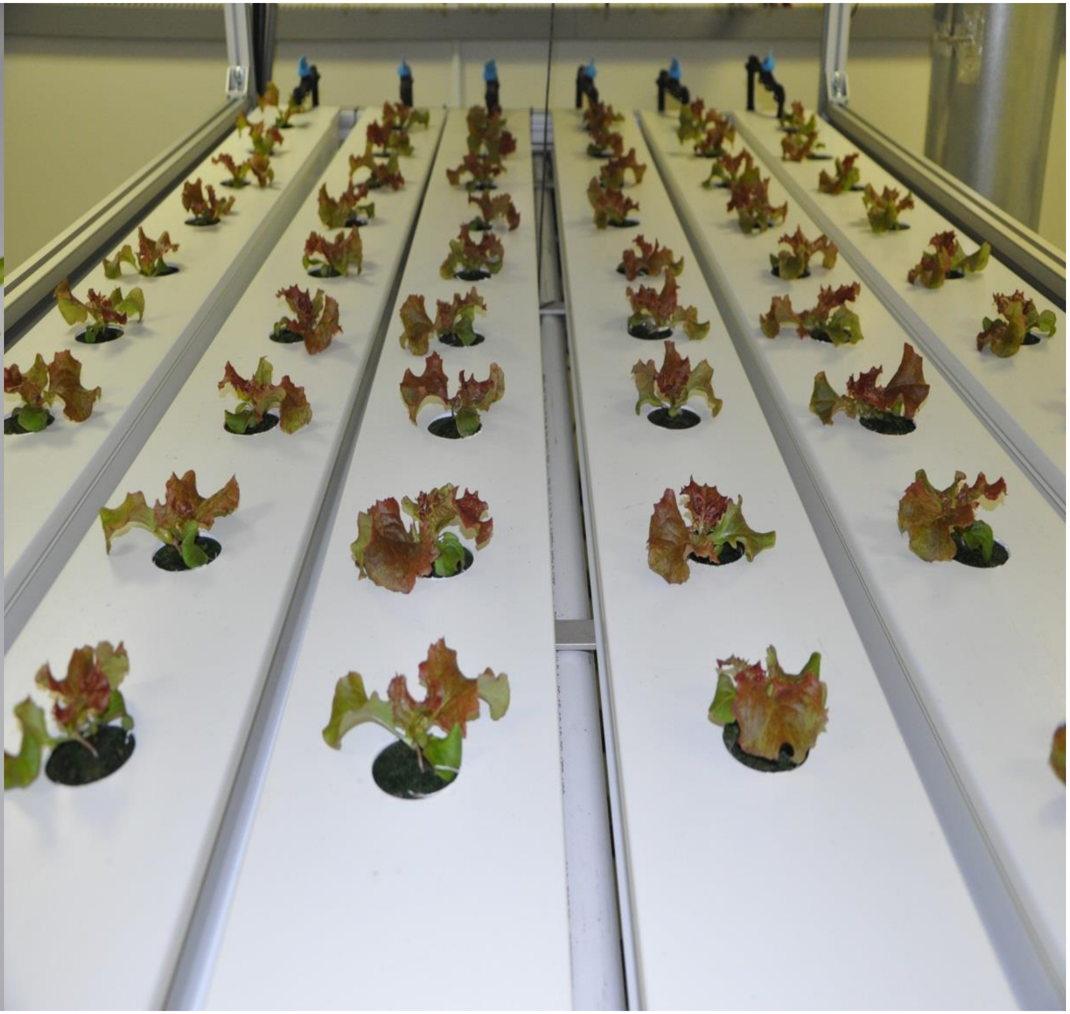
Seedling Stage

Nutrient Management with Hoagland Micronutrient Solution





Transplanting Stage



HOAGLAND SOLUTION

- **Hydroponic nutrient solution developed by Hoagland and Arnon in 1938.**
- **Classic and most popular nutrient solution in the scientific world.**
- **The Hoagland solution provides every nutrient necessary for plant growth.**

Potassium nitrate (KNO_3)
Magnesium sulphate heptahydrate ($MgSO_4 \bullet 7H_2O$)
potassium dihydrogen phosphate (KH_2PO_4)
Iron EDTA or Iron chelate (Fe-EDTA)
Boric Acid (H_3BO_3)
Copper Sulfate ($CuSO_4$)
Zinc sulfate heptahydrate ($ZnSO_4 \bullet 7H_2O$)
Manganese chloride ($MnCl_2 \bullet 4H_2O$)
Sodium molybdate ($Na_2MoO_4 \bullet 2H_2O$)
Calcium nitrate ($Ca(NO_3)_2 \bullet 4H_2O$)

Procedure

Make up stock solutions and store in separate bottles with appropriate label.
Add each component to 800 mL deionized water then fill to 1 L.
After the solution is mixed, it is ready to water plants.

Component	Stock Solution	mL Stock Solution/1L	
Macronutrients			
2M KNO_3	202 g/L	2.5	
1M $Ca(NO_3)_2 \bullet 4H_2O$	236 g/0.5L	2.5	
Iron (Sprint 138 iron chelate)	15 g/L	1.5	
2M $MgSO_4 \bullet 7H_2O$	493 g/L	1	
1M NH_4NO_3	80 g/L	1	
Micronutrients			
H_3BO_3	2.86 g/L	1	
$MnCl_2 \bullet 4H_2O$	1.81 g/L	1	
$ZnSO_4 \bullet 7H_2O$	0.22 g/L	1	
$CuSO_4 \bullet 5H_2O$	0.051 g/L	1	
$H_3MoO_4 \bullet H_2O$ or	0.09 g/L	1	
$Na_2MoO_4 \bullet 2H_2O$	0.12 g/L	1	
Phosphate			
1M KH_2PO_4 (pH to 6.0)	136 g/L	0.5	

Concentrations of each Element in Original Hoagland Solution

- N 210 ppm
- K 235 ppm
- Ca 200 ppm
- P 31 ppm
- S 64 ppm
- Mg 48 ppm
- B 0.5 ppm
- Fe 1 to 5 ppm
- Mn 0.5 ppm
- Zn 0.05 ppm
- Cu 0.02 ppm
- Mo 0.01 ppm

Modified Hoagland Solutions

Difference between Hoagland Solutions 1 and 2 is that Solution No.2 contains a portion of its nitrogen content as ammonium (NH_4), while in Solution No. 1; all of the nitrogen is in the nitrate (NO_3) form.

Stock Solution			To use: ml/ L
Solution No. 1			
1M	Potassium dihydrogen phosphate	(KH_2PO_4)	1.0
1M	Potassium nitrate	(KNO_3)	5.0
1M	Calcium nitrate	[$Ca(NO_3)_2.4H_2O$]	5.0
1M	Magnesium sulfate	($MgSO_4.7H_2O$)	2.0
Solution No. 2			
1M	Ammonium dihydrogen phosphate	($NH_4H_2PO_4$)	1.0
1M	Potassium nitrate	(KNO_3)	6.0
1M	Calcium nitrate	[$Ca(NO_3)_2.4H_2O$]	4.0
1M	Magnesium sulfate	($MgSO_4.7H_2O$)	2.0
Micronutrient stock solution			
Boric acid			2.86
Manganese Chloride			1.81
Zinc sulfate			0.22
Copper sulfate			0.08
Molybdate acid			0.02
		To use: 1 ml/L nutrient solution	
Iron			
For Solution No.1: 0.5% iron ammonium citrate			To use: 1 mL/ L
For Solution No. 2: 0.5% iron chelate			To use: 2 mL/ L

Management of Nutrient Solution

- Nutrition in hydroponics differs from that in soil as the **rooting volume is much smaller** and all nutrients are supplied in **solution**.
- P^H, EC and nutrient concentration of the nutrient solution should be continuously monitored and maintained. (changes in these factors have considerable effects on nutrient uptake, hence on nutrient status, growth and yield of the crop.)
- Water should be added to the nutrient solution in order to maintain the initial volume.
- The elements removed from the nutrient solution through plant uptake should be replenished.

Management of Nutrient Solution

(contd.)

- **In general, the optimum P^H for nutrient solution ranges between 6 -6.5.**

- **P^H markedly affects the availability of certain elements**
  - excessive uptake of micronutrients occur at lower P^H .
  - precipitation of micronutrients occur at higher P^H.

- **P^H needs to be adjusted by adding acid or alkali.**

  - Alkali – NaOH/ KOH (Sodium/Potassium hydroxide)
  - Acid – H_2SO_4/ HNO_3/ HCl (Sulfuric acid, Nitric acid, Hydrochloric acid)

Analysis of Nutrient Solution

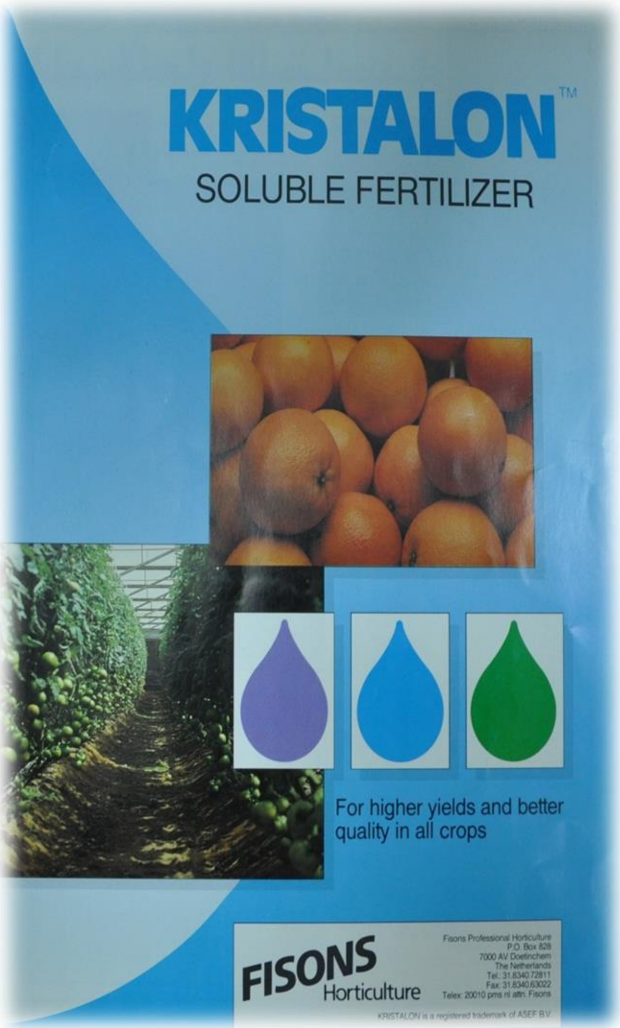
- pH and electrical conductivity should be monitored daily.

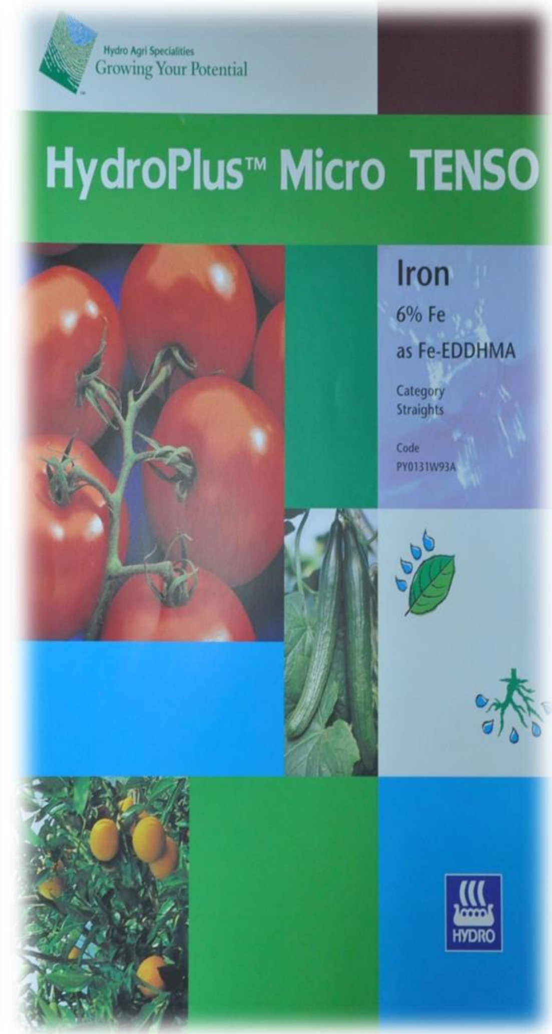
- Detailed nutrient solution analysis should be performed after the solution is mixed, and then every 5 days until the end of an experiment.

- Typical methodology of nutrient solution analysis involves the use of ion exchange chromatography using a high pressure liquid chromatograph (HPLC).

- An-ion and cat-ion exchange columns are used separately for the analysis of calcium (Ca^{+2}), magnesium (Mg^{+2}), ammonia (NH_4^+), sodium (Na^+),sulfate (SO_4^{-2}) phosphate (PO_4^{-3}), nitrate (NO_3^-), nitrite (NO_2^-), chlorine (Cl^-) & Potassium (K+)

Commercial Fertilizers for Hydroponics





Commercial Nutrient Compositions

It is wise to adapt the feeding system to the soil type AND the moment of the life cycle of the plant.
Whatever type is used, always alternate once weekly with the Kristalon Special 18-18-18+2+TE.

NO_3-N	NH_4-N	Ur-N	KRISTALON	N	P_2O_5	K_2O	MgO	B	Mo	Cu	Fe	Mn	Zn	S	EC		
1,8	17,2		LILAC	19	6	6		0,025	0,001	0,01				18	1,7	soils pH of 7 or higher / تربة pH فيها ٧ او اكثر	early season, high pH soils / بداية الموسم ، تربه pH فيها عالية
5,1	11,9		BLUE	17	6	18	0,3	0,025	0,001	0,01				12	1,6		vegetative period, high pH soils / فترة النمو الخضري تربه pH فيها عالية
6,8	5,2		WHITE	12	4	24	6	0,025	0,001	0,01				10	1,4		generative period, high pH soils / فترة الانتاج تربه pH فيها عالية
3,9	9,1		YELLOW	13	40	13		0,025	0,001	0,01				1	1,0	optional / اختياري	early season, root stimulation / بداية الموسم ، للحث على تكوين الجذور
10,1	1,9		RED	12	12	36	1	0,025	0,001	0,01				1	1,3	recommended / موصى به	late season, flower/fruit stimulation / آخر الموسم ، للحث على الازهار والاثمار
5,5	3,8	9,7	GREENLABEL	19	19	19	1,5	0,025	0,001	0,01				1	0,9	when required / عند الحاجه	general purpose N, P and K / لاغراض عامه ، نيتروجين ، فوسفور ، بوتاسيوم
5,3	3,6	9,1	SPECIAL	18	18	18	2	0,04	0,009	0,06	0,13	0,20	0,05	2	0,9	once weekly / مرة في الاسبوع	general purpose including all trace elements, to alternate with all other types weekly / للاغراض العامه محتويا على عناصر نادره للتبادل مع جميع الانواع الاخرى اسبوعيا
5,6	14,4		LILAC LABEL	20	8	8	1	0,025	0,001	0,01				12	1,6	soils pH lower than 7 / تربة pH فيها اقل من ٧	early season, normal soils / بداية الموسم ، تربه عاديه
11,9	7,1		BLUE LABEL	19	6	20	3	0,025	0,001	0,01				3	1,4		vegetative period, normal soils / فترة النمو الخضري ، تربه عاديه
11,3	3,7		WHITE LABEL	15	5	30	3	0,025	0,001	0,01				3	1,3		generative period, normal soils / فترة الانتاج - تربه عاديه

من الحكمه تكييف نظام التغذيه مع نوع التربه ومراحل دورة حياة النبات . مهما كان النوع المستعمل فانه يفضل ان يستعمل معه بالتناوب كريستالون ٢:TE : ١٨ : ١٨ : ١٨ (18-18-18+2+TE) مرة كل اسبوع .


CAUTION: PLEASE DO NOT LEAN
CAUTION: PLEASE DONT TOUCH
CAUTION: PLEASE DO NOT LEAN
CAUTION: PLEASE DONT TOUCH

It’s Possible…

with MAPS

…requires research and fine tuning

EXPERIMENTAL DESIGNS IN MAPS

Since reception, five experiments were conducted to master various techniques employed in the prototype unit.

A) General Research Activity entitled "Optimization of System Functions and Environmental Parameters and Testing of Modular Agricultural Production System (MAPS)" (FA093G) is completed.

Objectives:

- To upgrade the ambient environment management capability in MAPS room and evaluate the effect of modifications on ambient environmental conditions and functionality of automated sensor system.
- To modify the system functions cost-effectively and evaluate the effect on environmental parameters influencing plant growth in MAPS.
- To test-run the Modular Agricultural Production System (MAPS) with experimental crops to optimize the system function.

B) Seed Money Project entitled "Influence of Light Emitting Diodes (LED) Light on the Productivity and Quality of Selected Crops in a Closed Plant Factory System" is ongoing.

Objectives:

- Development of specific LED light recipes for enhanced productivity and quality of selected crop classes in the MAPS.
- Physiological and molecular characterization of selected crop plants grown in MAPS under different LED light quality treatments.

Experimental Designs in MAPS

Growth and Yield of Lettuce as Affected by LED Light Qualities in a Closed Production System.

- Blue LED
- White LED
- Red LED

Experimental Designs in MAPS

Experimental Designs in MAPS

Effect of Light Quality and Photoperiod on Growth and Yield of Hydroponic Lettuce (*Lactuca sativa* cv. New red fire) in a Modular Agricultural Production System.

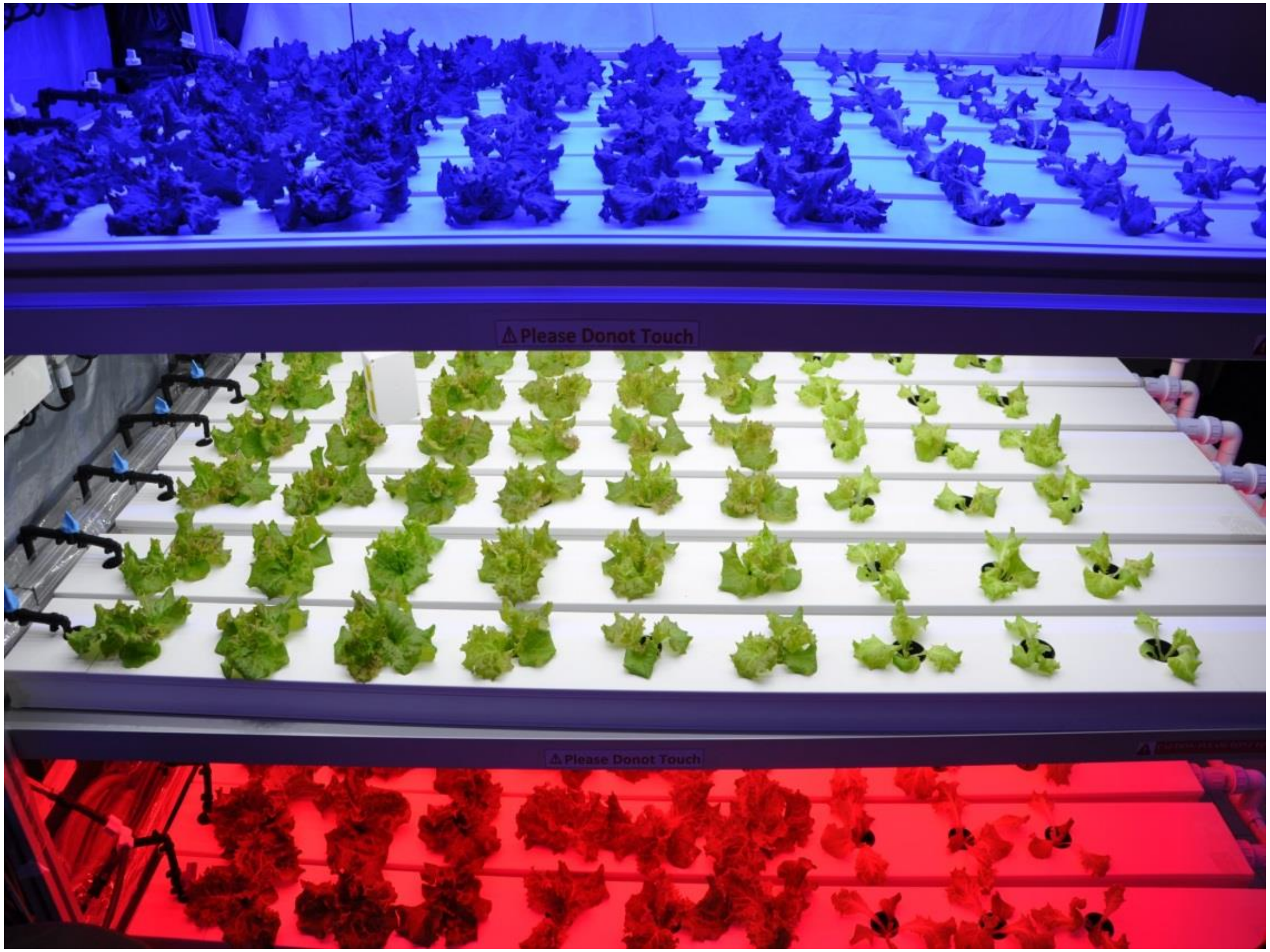
<u>**Light Quality**</u>

- Blue LED
- White LED
- Red LED

<u>**Photoperiod**</u>

- Light/Dark : 24/0 Hrs.
- Light/Dark : 16/8 Hrs.
- Light/Dark : 8/16 Hrs.

Experimental Designs in MAPS



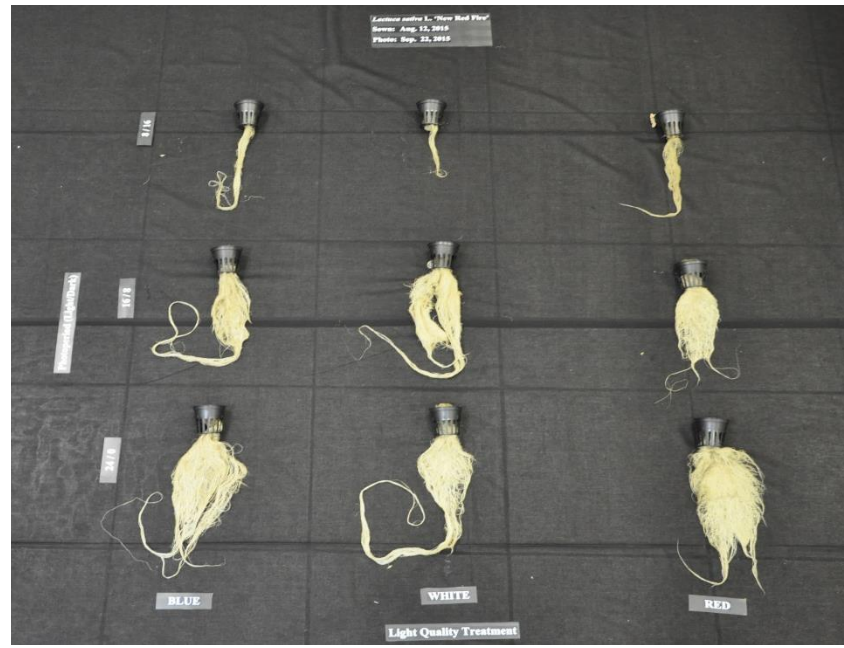
Experimental Designs in MAPS

Experimental Designs in MAPS

Experimental Designs in MAPS

Effect of Light Quality and Photoperiod on Growth and Yield

Effect of Light Quality and Photoperiod on Root Growth

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THANK YOU

biotechkitty@gmail.com

ksugumaran@kisr.edu.kw

+965 - 99608890