Introduction to Plant Factory (Controlled Environment)

Protected Horticulture
– *Hydroponics*

Jongyun Kim

Changes in Plant Production

18 C
Organic Production

→

19-20 C
Production with Chemicals

↓

Late 20 C
Organic Production & Hydroponics

→

21 C
Plant Factory
Hydroponics
Organic Production

Hydroponics

Water Culture?

Nutrient Solution Culture?

Soilless Culture?

Hydro (water) + Ponos (labor)

- Gerick's application of hydroponics soon provides itself by providing food for troops stationed on nonarable islands in the Pacific in the early 1940s

Comparison

Cultural practice	Soil	Soilless
Plant Nutrition	Difficult to control	Easy control
Fertilization	High / Inefficient	Less / Efficient
Media Sterilization	2-3 weeks	Short time
Weed control	Frequent	Less or none
Diseases, Insect	Happens often Rotation required	Less disease
Plant Spacing	Limited	Closer spacing

Comparison

Cultural practice	Soil	Soilless
Water	Stress	No stress
Sanitation	Sometimes problem	Little problem
Quality	Acceptable	Good
Yield	Normal	2-3 times more
Initial Cost	Cheaper	Expensive

2018 Plant Factory – Hydropinics

Importance and Benefits

Producer

- **Automation**
- **Land use efficient**
- Year-thru high quality production
- Urban production

Consumer

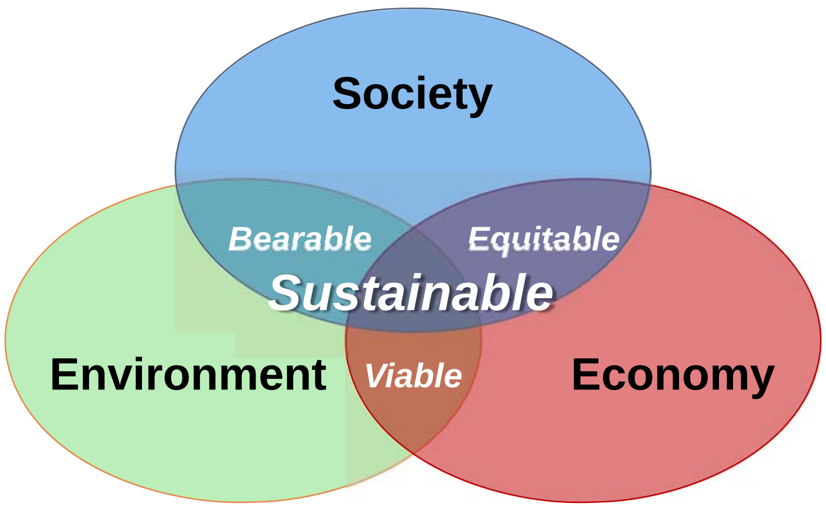
- **Fresh** product with **Safe** and **High quality**
- Year-thru
- Health Benefits

Environment

- Environmental Friendly
- Less pollutant
- Recycled nutrient solution

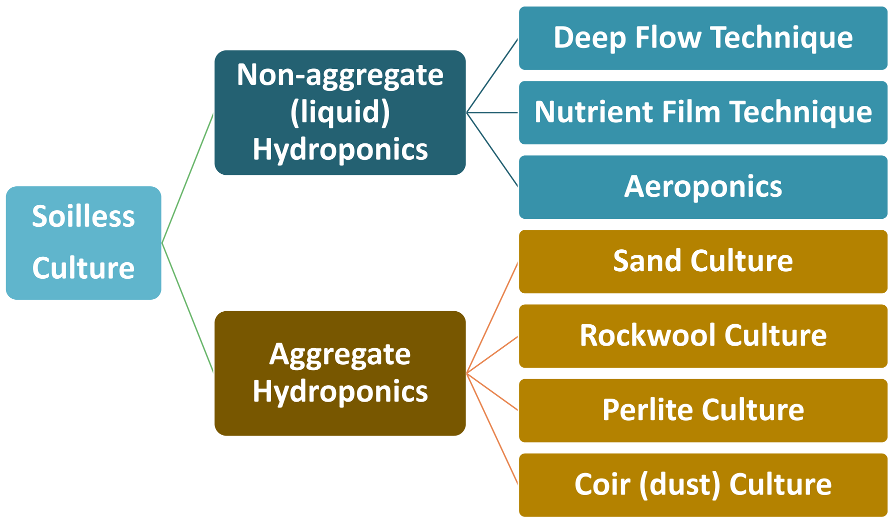
2018 Plant Factory – Hydropinics

Sustainability

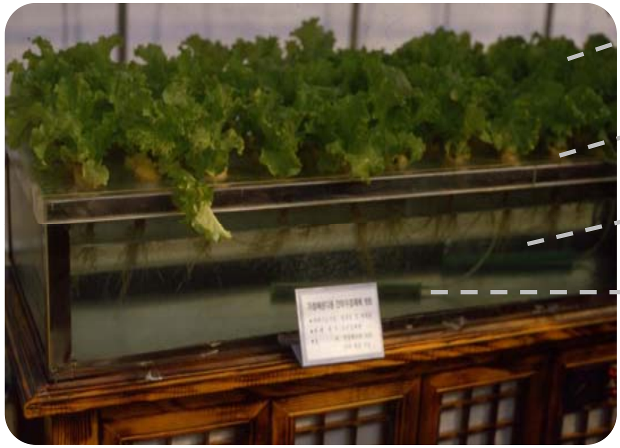


2018 Plant Factory – Hydropinics

Classification of Hydroponics



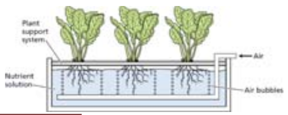
Deep Flow Technique (DFT)



- Lettuce
- Sponge for plant fixing
- Nutrient solution
- Bubbler for oxygen supply

2018 Plant Factory – Hydropinics

Pros and Cons of DFT



Advantage

- **High volume** of NS
  → Little temperature fluctuation
  → Stable nutrient concentration and pH
- **Little damage** when the circulation pump is out of order

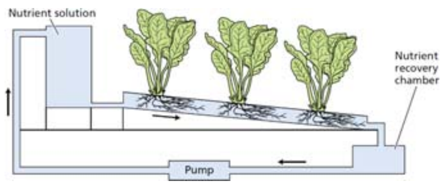
Disadvantage

- Difficult in water control → difficult in **growth control**
- **Higher cost** due to high volume of NS
- Critical damage with **disease** spread
- **Lack of oxygen** supply

2018 Plant Factory – Hydropinics

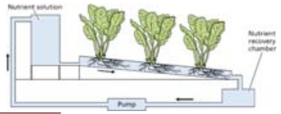
Nutrient Film Technique (NFT)

- Plants are grown with their **root systems** contained in plastic film through which **nutrient solution** is **continuously circulated**
- The least acceptable slope was about 1 in 100 or 1 in 80
- Many applied method were developed



Pot Using Home NFT

Pros and Cons of NFT



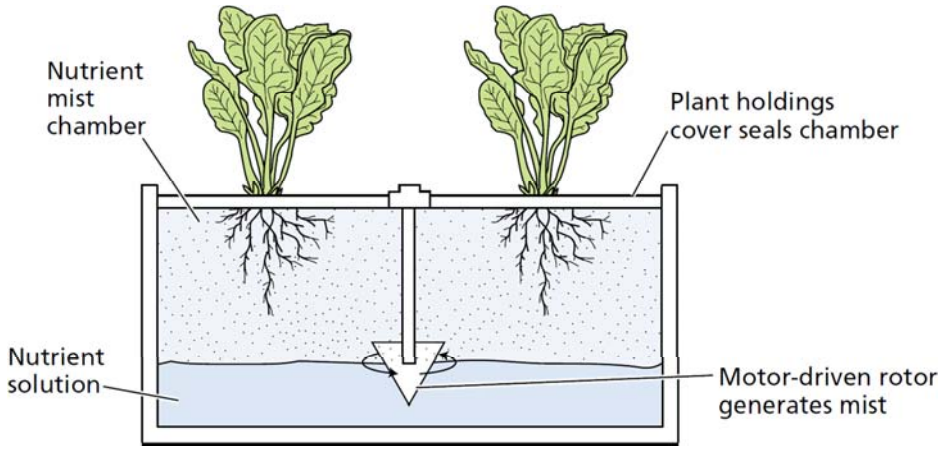
Advantage

- **Less** usage of NS
- **Easier** change in NS
- Pesticide treatment available
- **Circulation** types → less pollution
- **Cheaper** investment

Disadvantage

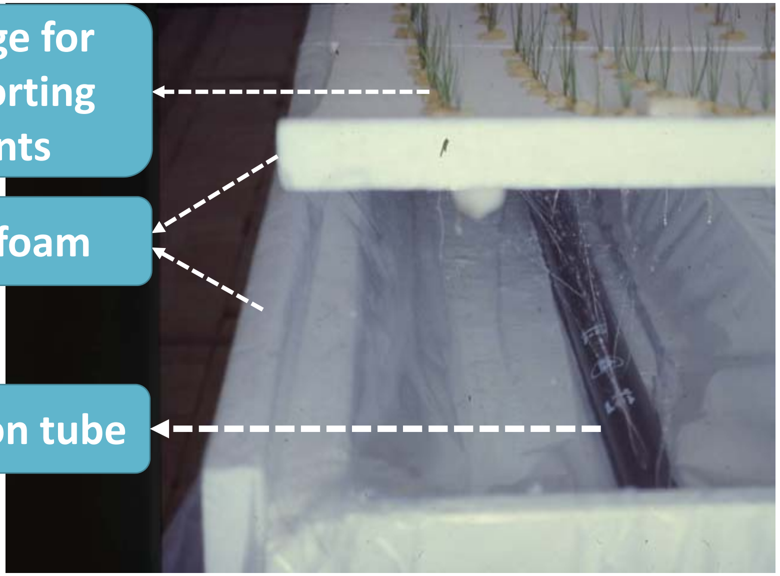
- **Difficult in temp** control of NS
- **More attention** is required due to small volume of NS
- **Huge damage** when NS circulation stops

Aeroponics



Potato Seed Tuber Production

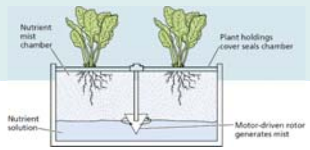
Simple Aeroponics



Pros and Cons of Aeroponics

Advantage

- **Less** usage of NS
- **Easier** change in NS
- **Easier** sanitation
- Good growth
- **Efficient** spacing



Disadvantage

- **Expensive**
- **Difficult temp control**
- Problematic when **nozzle is clogged**
- **Huge damage** when electrical shortage

Sand Culture

Pros and Cons of Sand Culture

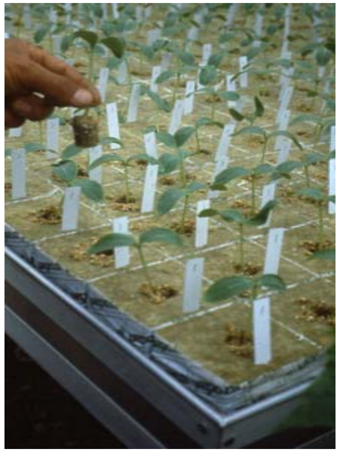
Advantage

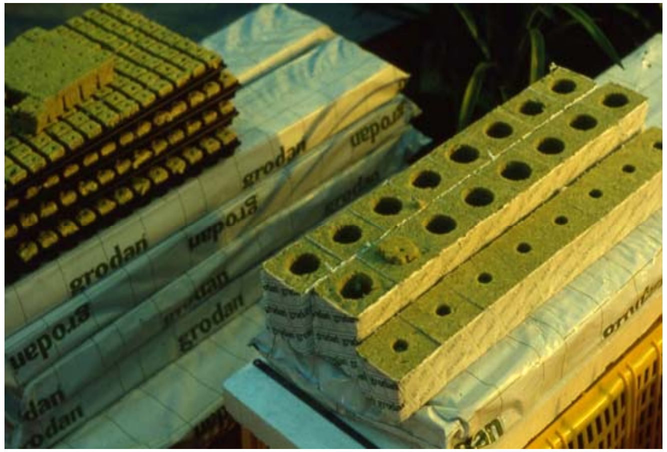
- Small particle size → root distribution
- Good aeration
- No-circulation type
- Better water holding capacity than gravel culture

Disadvantage

- Sand sanitation required
- More NS is required than circulation type
- Salt accumulation
- Clogging on drippers
- Heavy media

Rockwool Culture





Pros and Cons of Rockwool Culture

nth on there
이라 쉽게 컨트롤 워터레벨, 뉴트리언트 레벨

스타팅포인트에
(*salb에 루트 스프레딩
녹음들어야함)

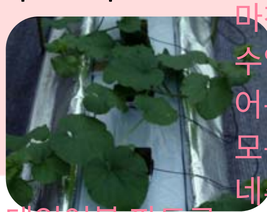
Advantage

- Easy control of NS
- Less disease
- Modified block
- Starting from nothing

Disadvantage

- No visual changes
- Difficult in medium temperature control
- Salt accumulation
- Disposal problem

다른 서브스트
레이트는 색갈
은거 보고 가늠
가능 워터, 뉴트
리언트 솔이 얼
마나 있는지 가
늠x
????(녹음)
마찬가지로 볼
수없어서 솔트
어큐물 있어도
모름
네츄럴 띵이아
님--> 쓰레기처
리



락울--> 서스테인어블 파트로
넘어가는중 요샌.

Perlite Culture

그라네이트에서 옴 보미큘레이트: 어큐뮬레이션 파트 크
펄라이트 장점: 굳 에어레이션, 인사이드에 낫띵
하이드로포닉스에서, 낫띵이기때문에 이지투 컨트롤

워터 리메인 낮음
WHC 작기때문
--> 이지투 컨트롤 뉴트리언트 솔루션

캐미컬, 베큠 등으로 클린
잘 깨지지않아서

Pros and Cons of Perlite Culture

Advantage

- Good aeration, water filtration
- Easy fertilization
- Easy sanitation
- Longer lifespan

Disadvantage

- No CEC
- No buffering capacity
- Dust problem
- Difficult in recycling after multiple use

뉴트리언트 홀딩 x cation
exchnge cap 낮음
--> 항상 뉴트리언트 솔루
션에 의존
노버퍼링 캐패시티 :
더스트 (젖었을땐 문제 x)

스테이블, 서스테인어블 디벨롭먼트를 위해
코코핏 더스트임
람지 whc 빅 포어, 굳 버퍼링 캐패시티
되게 시밀러 투 락울
블락형태로 제공가능..?
슬레브 위에 코이어 더스트

Coir Dust Culture

Pros and Cons of Coir Culture

Advantage

- **Cheaper** than peatmoss
- Light weight 물먹ㅇ을시무거움
- Block or bag types 가벼우면 인력적음
- Organic matter → **recycling** 올개닉이기때문에 리사이클가능 (높음)
- Higher water holding capacity with rich in **porosity** 90% 포어
- **Buffering capacity**

펄라이트와 다르게
워터 홀드

Disadvantage

- **Variation** across the manufacturer or origins
- Require more experiences to control nutrient solution

만드는 컨트리에 따라 인디아, 필리핀 스리랑카 스탠다드(ph, size)필요
높은 whc nhc --> remain 가능성--> ! 이지 투 컨트롤

Nutrient Solution

- Knop (Germany)
  - Only KNO_3, $Ca(NO_3)_2$, KH_2PO_4, $MgSO_4$, an iron salt
    를 섞은것들 이젠 잘안씀 (녹음)
- Hoagland Solution 미국에서 발명, 이거많이씀, 마크로,—마이크로 모든 엘레멘트
  - Contains all of the known mineral elements for plant
    다있음 NPK Ca Mg 등등등
- Asian Nutrient Solutions
  - Yamazaki Solution 한국원예시험장 원시
  - Korean Wonshi (韓國園藝試驗場)
  - Japanese Enshi (日本園藝試驗場)
    일본원예시험장 엔시

각 크롭당 뉴트리언트 리콰이먼트 달라서 별별로 만듬

Stock Solutions

To prevent precipitation

스탁: 맨날 만들기 힘드니까 20톤 워터 등등 많은 양의 뉴트리언트 솔류션 농도높은 스탁 만들어서 뉴트리언트 필요할때만다 희석시켜
침전 주의해야함,
킬레이터 사용

Modified Hoagland Solution

Compound	Molecular weight	Concentration of stock solution	Concentration of stock solution	Volume of stock solution per liter of final solution	Element	Final concentration of element	
	g mol^{-1}	mM	g L^{-1}	mL		µM	ppm
Macronutrients							
KNO_3	101.10	1,000	101.10	6.0	N	16,000	224
$Ca(NO_3)_2 \cdot 4H_2O$	236.16	1,000	236.16	4.0	K	6,000	235
$NH_4H_2PO_4$	115.08	1,000	115.08	2.0	Ca	4,000	160
$MgSO_4 \cdot 7H_2O$	246.48	1,000	246.49	1.0	P	2,000	62
					S	1,000	32
					Mg	1,000	24
Micronutrients							
KCl	74.55	25	1.864	2.0	Cl	50	1.77
H_3BO_3	61.83	12.5	0.773		B	25	0.27
$MnSO_4 \cdot H_2O$	169.01	1.0	0.169		Mn	2.0	0.11
$ZnSO_4 \cdot 7H_2O$	287.54	1.0	0.288		Zn	2.0	0.13
$CuSO_4 \cdot 5H_2O$	249.68	0.25	0.062		Cu	0.5	0.03
H_2MoO_4 (85% MoO_3)	161.97	0.25	0.040		Mo	0.5	0.05
NaFeDTPA (10% Fe)	468.20	64	30.0	0.3–1.0	Fe	16.1–53.7	1.00–3.00
Optional[a]							
$NiSO_4 \cdot 6H_2O$	262.86	0.25	0.066	2.0	Ni	0.5	0.03
$Na_2SiO_3 \cdot 9H_2O$	284.20	1,000	284.20	1.0	Si	1,000	28

Source: After Epstein 1972.

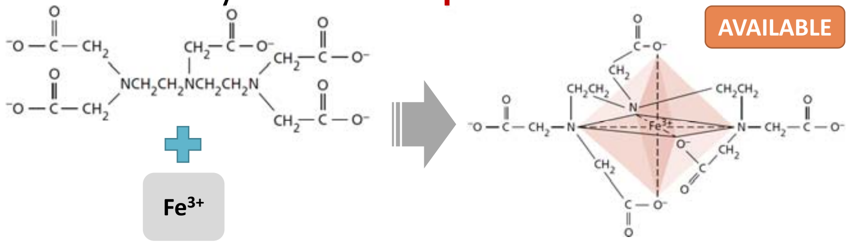
DTPA, E~ 킬레이터 다음페이지:

Chelators

캐미컬간 리엑션 못일어나게 따로따로 만들었다가 줄때 한번에 합쳐야함

- In nutrient solution, precipitation of iron
  ➔ unavailable to the plant ➔ Need something

- Chelating agents
  - EDTA: **e**thylene**d**iamine**t**etraacetic **a**cid
  - DTPA: **d**iethylene**t**riamine**p**entaacetic **a**cid



Stock Solutions and Mixer

Stock Solutions

To prevent precipitation

Feeding Water and Nutrient

- **Soilless media require proper feeding**
- **Depending on species and growth stages**
- **Requires experience and cumulative data**

빠져나가는 액

- **Leachate Analysis**
  - Checking EC and pH of drainage solution
  - Adjust feeding nutrient solution

What to CONSIDER

EC | pH | DO | Temp

EC/pH Control for Media

Increase EC
- Increase fertilizer rates
- Increase the fertilizer frequency

Increase pH
- Nitrate-based fertilizer
- Add hydrated lime or potassium bicarbonate

Decrease EC
- Lower fertilizer rates
- Leaching with water

Decrease pH
- Ammonium fertilizer
- Acid drenches

EC control

- **Generally 1.5-3.0 dS/m → species specific**
  - Fruit vegetable : 2.0-3.0 dS/m
  - Leafy vegetable : 1.2-1.8 dS/m
  - Ornamental plants : 1.5-2.0 dS/m
- **Control the concentration based on weather**
  - Higher consumption → lower the concentration
- **Specific ion deficiency can occur**
  - ISFET (ion-selective field effect transistor) sensor

EC Sensor → EC Controller → Pumping Conc. NS

pH control

- Generally between 5.5-6.5 (weak acidic)
- Decrease in pH when cation uptake increase
  - K^+, Ca^{2+}, Mg^{2+}, NH_4^+ uptake → release H^+
- Increase in pH when anion uptake increase
- Decrease pH through adding acids
  - H_2SO_4, H_3PO_4, HNO_3, $(NH_4)_2SO_4$
- Increase pH through adding KOH / NaOH

pH Sensor → pH Controller → Adding acid/OH

Dissolved Oxygen (DO)

- Oxygen for respiration and proper growth
- Factors affecting dissolved oxygen

Temperature	• High temperature requires more oxygen • DO decreases with higher temperature
Light	• High light intensity → more transpiration and respiration
Species dependent	• Cucumber require x2 oxygen than tomato
Hydroponic system	• DFT requires more attention

여기뭔가 중요한듯 (23)(녹음

DO Control

- **Oxygen Deficit Symptom**
  - Less uptake of water and nutrient → Deficit symptom
  - Less hormonal biosynthesis (cytokinin) 노화방지, 에틸렌도 같이 뿜, ( )
  - Less root hair development 그로우 줘야
  - Higher ethylene → Root senescence

성숙 노화관련

- **How to increase DO**
  - Control the level (height) of the nutrient solution
  - Using air bubbler or aerator
  - Decrease the water temperature

Solution Temperature

녹음파일 #21

- Effect of solution temperature

Photosynthesis	• Optimal temperature
Respiration	• Q10 effect
Dissolved Oxygen	• Higher temperature → less DO
Plant Growth	• High temp → thin and many lateral roots and narrow leaves
Nutrition uptake	• Low T: less P, K, NO_3, Ca, Mg uptake • High T: Excess N, K → less Ca

온도에 따라, 10도가 증가할수록 엑티비티가 인크리즈(주로)/디크리즈 -(이건 종과 어떤 리액션인지 에따라다름0)

Fertigation Methods

time base 식물이나 env factor 고려 x

Timer Control	• Based on time schedule • Simple automation
DLI Control	• Water use ∝ Daily Light Integral • Timer at night
Weight based Control	• Using load-cell (weight measure) • Calculating evapotranspiration
Soil Moisture Sensor Control	• Based on VWC measurement • FDR sensors

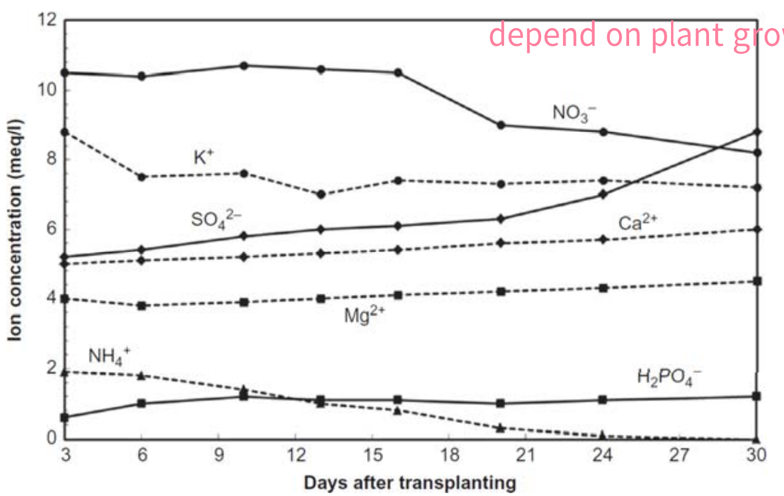
DLI 가 비례하므로

no ferigate @ night

이거 식물 자라면 어떻게 재지.. 식물 무게는 별로 변화가없음. 무게의 변화== 증발산량

* soil EC 물이 대부분.

Ionic Conc. w/ constant EC



depend on plant grow, spacing

Ion Specific Quantification

Ion Chromatography

Atomic Absorption Spectrophotometer

Inductively Coupled Plasma

Portable Spectrophotometer

accuracy 는 그렇게 높지않음