NSF NRT-InFEWS: Indigenous Food, Energy, and Water Security and Sovereignty
Presents:

Food, Energy and Water (FEWS) Learning Modules

June 2021

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MODULE INTRODUCTION:

DR. MURAT KACIRA - DIRECTOR, CONTROLLED ENVIRONMENT AGRICULTURE CENTER

MODULE 1: DINÉ FOOD SOVEREIGNTY & AGRICULTURE

JAYMUS LEE - PSM IN CONTROLLED ENVIRONMENT AGRICULTURE, UNIVERSITY OF ARIZONA

- Lecture
- Zoom Poll Question
- Jamboard (Slide 1)
- Lunch Break Discussion Prompt

MODULE 2: CONTROLLED ENVIRONMENT AGRICULTURE & GREENHOUSE DESIGN

AMY PIERCE, MS BIOSYSTEMS ENGINEERING

- Lecture
- Zoom Poll Question
- Jamboard (Slide 2)

MODULE 3: HYDROPONICS & GROWING SYSTEMS

ALEXANDRA TRAHAN, MS, ENVIRONMENTAL SCIENCE

- Lecture
- Jamboard (Slide 3)

MODULE 4: CEA PLANT NUTRITION

RUTH PANNILL, MS NATURAL RESOURCES AND ENVIRONMENT

- Lecture
- Zoom Poll Question

MODULE 5: DINÉ COLLEGE HOOP HOUSE PROJECT

JAYMUS LEE - PSM IN CONTROLLED ENVIRONMENT AGRICULTURE, UNIVERSITY OF ARIZONA

- Lecture
- Application and Review

REVIEW: INTRODUCTION TO HOMEWORK & EQUATIONS

AMY PIERCE, MS BIOSYSTEMS ENGINEERING & JAYMUS LEE - PSM IN CONTROLLED ENVIRONMENT AGRICULTURE, UNIVERSITY OF ARIZONA

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INDIGE-FEWSS FOOD MODULES

HYDROPONIC GROWING SYSTEMS

Presented by: Alexandra Trahan

THE UNIVERSITY OF ARIZONA

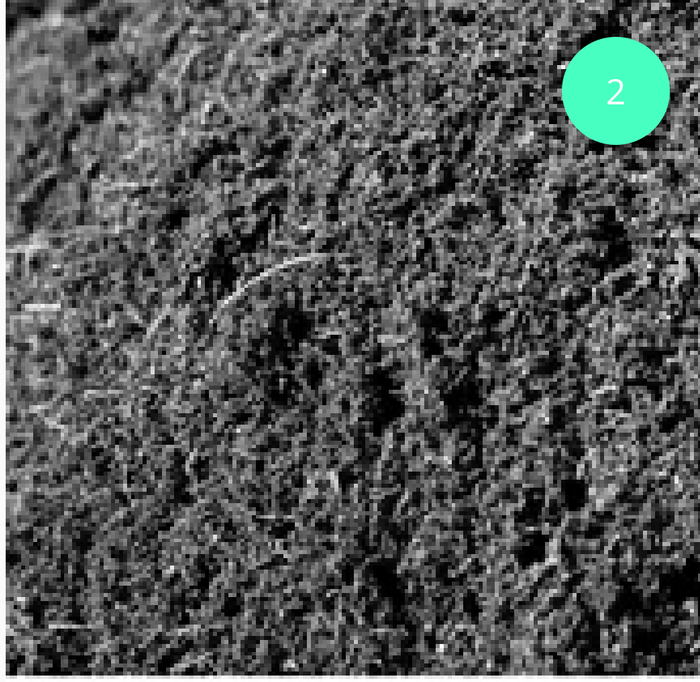
Learning Objectives

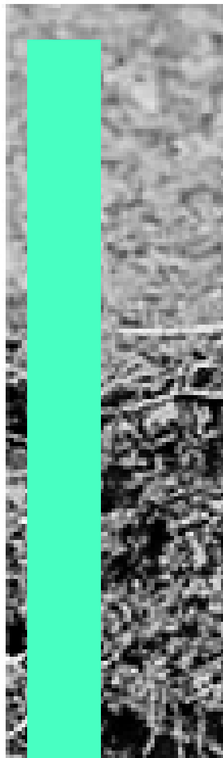
Students will be able to:

1. Name and describe:
    a. Hydroponic systems,
    b. Plant types to be grown in each system, and
    c. Benefits/challenges of each system
2. Name different soilless substrates used for hydroponic systems
3. Understand the different culture system types

Presentation Outline:

- Introduction
- Hydroponics
- Types of Culture Systems
- Growing Media
- Growing Systems
- Irrigation & Fertilization
- Nutrient Solution Introduction





Introduction

A type of horticulture and a subset of hydroculture that involves growing plants (usually crops) without soil, by using mineral nutrient solutions in an aqueous solvent. The term was coined by Dr. W.F. Gericke in 1936.

Hydro + *Ponos*

Greek for water

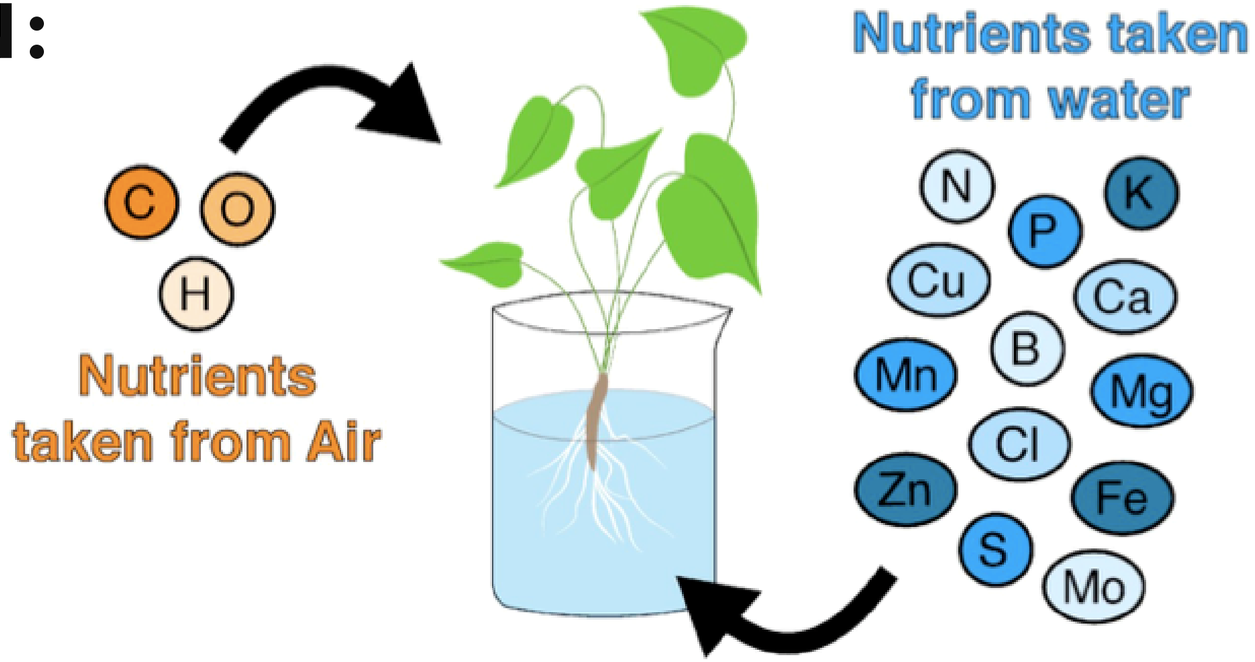
Greek for working

Introduction

Hydroponics

CLASSIFIED BASED ON:

1. Location of roots:
   - Aggregate culture
   - Liquid culture
2. Nutrient solution:
   - Open system
   - Closed
   - Semi-closed system



Introduction

The Ifugao community has lived here for thousands of years. This growing system persists for 2000 years and includes:

- Terraced pond fields
- Irrigation
- Water harvesting
- Soil Conservation
- Pest control regime with herbs
- & more

The Rice Terraces of the Philippine Cordilleras, Ifugao Province, Cordillera Region, Luzon Island

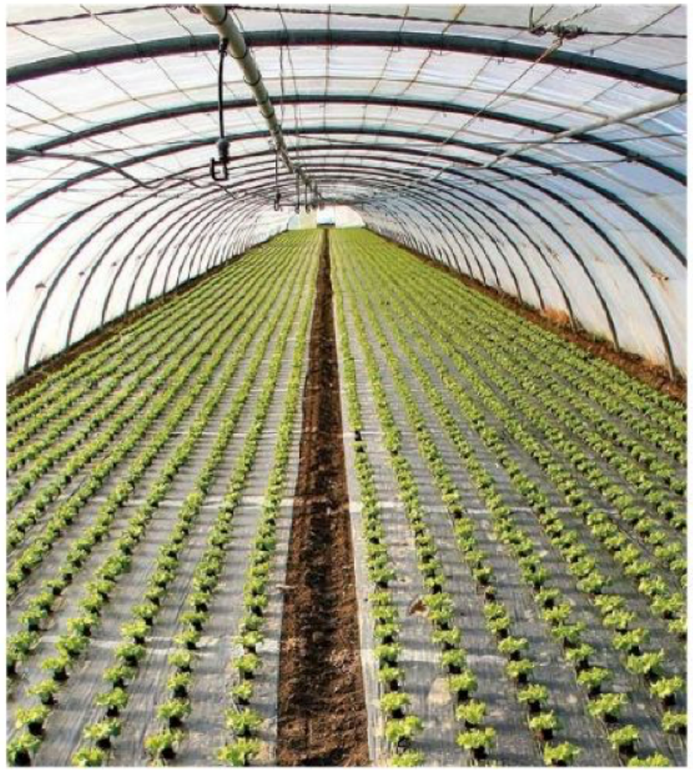
Introduction

Growing System

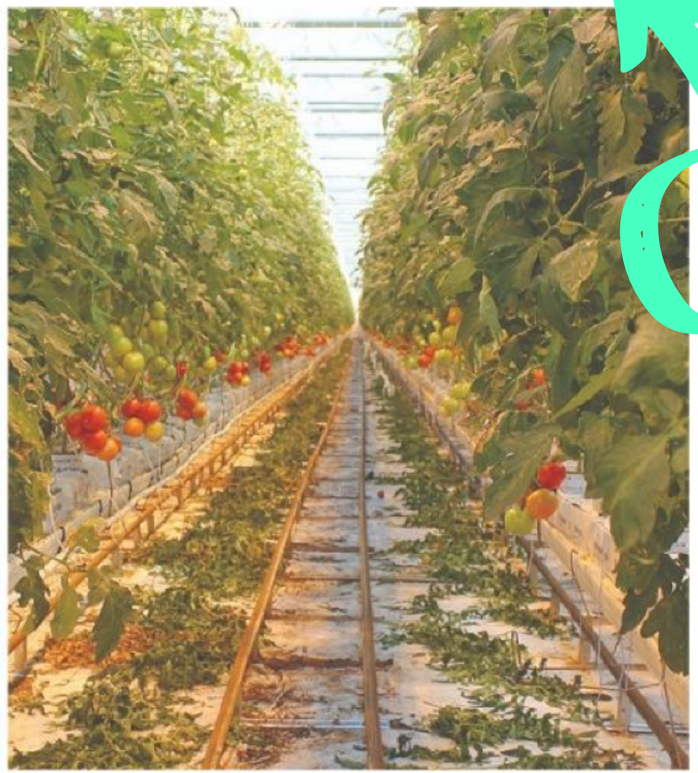
Definition:

A type of system that facilitates the growth of plants/crops.

Soil Farming



Hydroponic Farming



Comparisons

NATURAL SOIL

- Contains natural nutrients
- Excessive application of pesticides/herbicides
- High microbial activity

Navajo Corn field using natural soil

SOILLESS AGGREGATE

- Nutrients need to be added
- A variety of inorganic & organic materials
- Have less microbial activity

Greenhouse Corn using aggregates

SOURCE: NORTH WIND PICTURE ARCHIVES AND PURDUE AGRICULTURE

Challenges

Soil:

- Unpredictable nutrient availability & pathogen pressures
- Fungal pathogens represent over 90% of disease-caused crop losses
- Fungal spores remain dormant for years
- Excess water & fertilizers are lost to ground/surface water

Hydroponics:

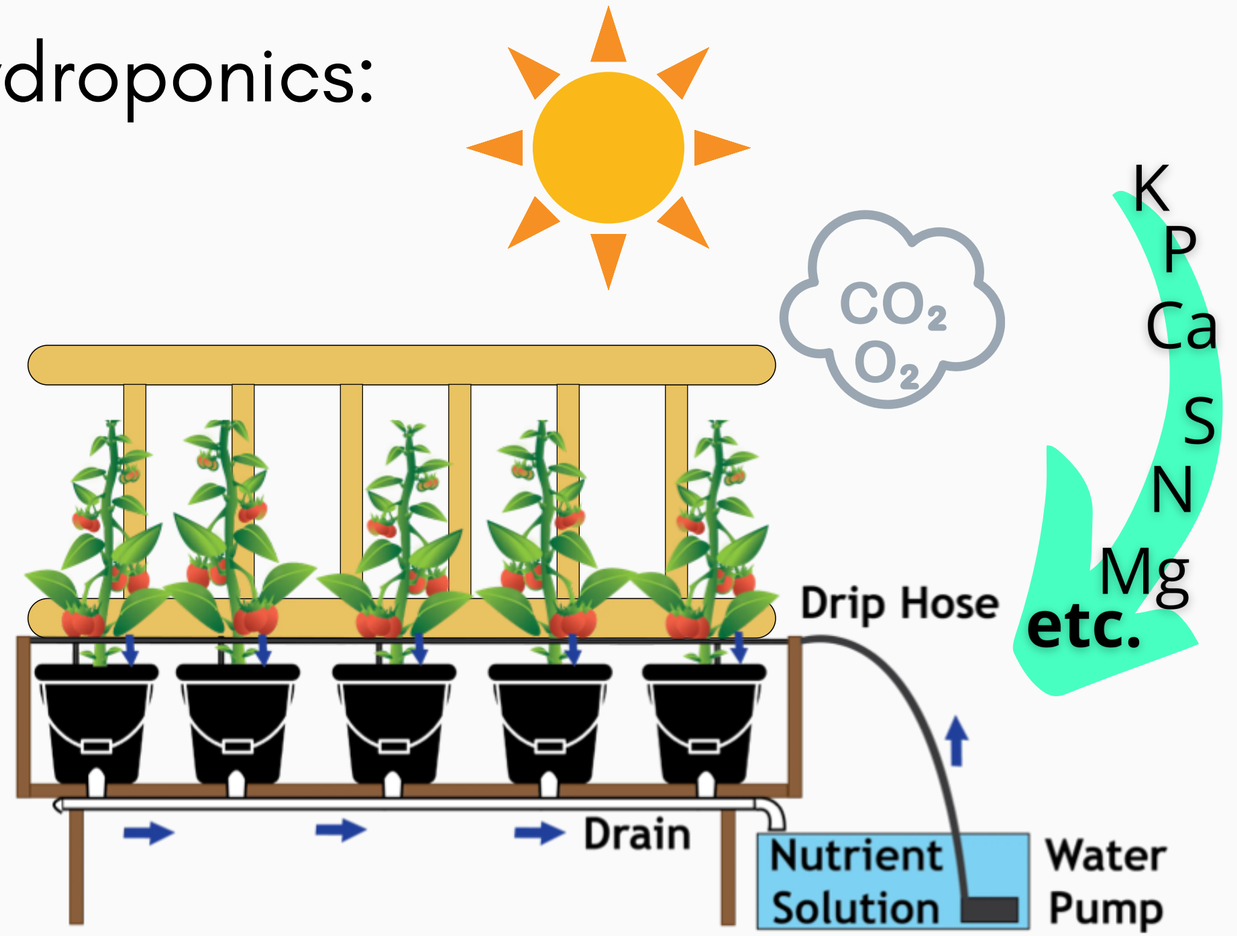
- Pathogen pressures
- Fungal pathogens represent over 90% of disease-caused crop losses
- Fungal spores remain dormant for years

TOLLEFSON, S., PLS 217 LECTURE SLIDES, UNIVERSITY OF ARIZONA (2019)

Introduction

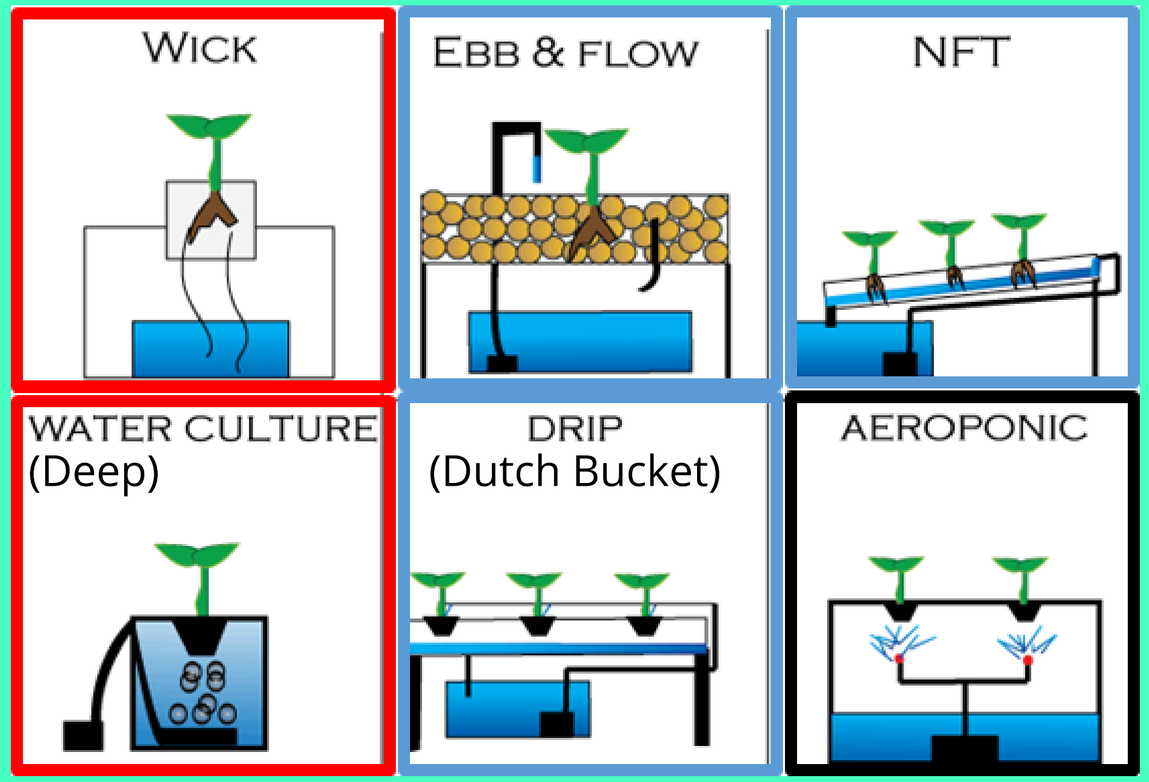
Basic Requirements of Hydroponics:

- Growing media
- Nutrient solution
- Temperature
- Light
- Air
- Supporting materials
- Water
- Mineral nutrient



Hydroponic Culture Systems

Liquid Culture: *Hydroponics with water and nutrient solution. Requiring consistent and immediate control of the nutrition.*
Aggregate Culture: *Hydroponics with water, nutrient solution, and a solid substrate. Requiring less intensive management of nutrient solutions.*



SOURCE: APPLIED PLANT PHYSIOLOGY; PROF. TANYA M. QUIST; SCHOOL OF PLANT SCIENCES; U OF A

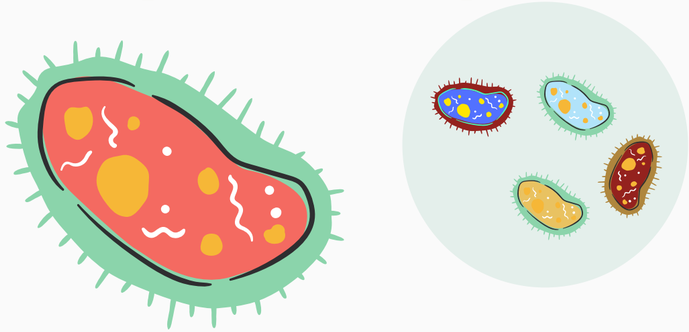
Characteristics of Growing Media

"Growing Media/Substrate"- A liquid/solid substance that facilitates chemical and/or biological interactions and physical support.

Chemical Properties

Physical Properties

Biological Properties



SOURCE: APPLIED PLANT PHYSIOLOGY; PROF. TANYA M. QUIST; SCHOOL OF PLANT SCIENCES; U OF A

Characteristics of Growing Media

Chemical properties

- Electrical Conductivity
- Cation Exchange Capacity
  - Lower CEC is suitable for hydroponics, as it allows a quick adjustment of the root zone chemical environment.
- pH

Biological properties

- Chemical & physical characteristics impact the biotic composition of the root environment

Physical Properties

- Porosity (air porosity and total porosity)
- Bulk density
- Water holding capacity
- Others: Color (radiation absorption) of the container (and substrate); container shape, size, & height; gravel base and drainage

Growing Media

ROCKWOOL

- Little (or no) CEC
- High WHC(~80%)
- Moderate air porosity (~18%)
- Very consistent in performance

Composition:

- Made by melting rock and spinning it into extremely thin and long fibers to press into cubes/sheets

Pros:

- Good water retention
- Easy disposal
- Very consistent in performance

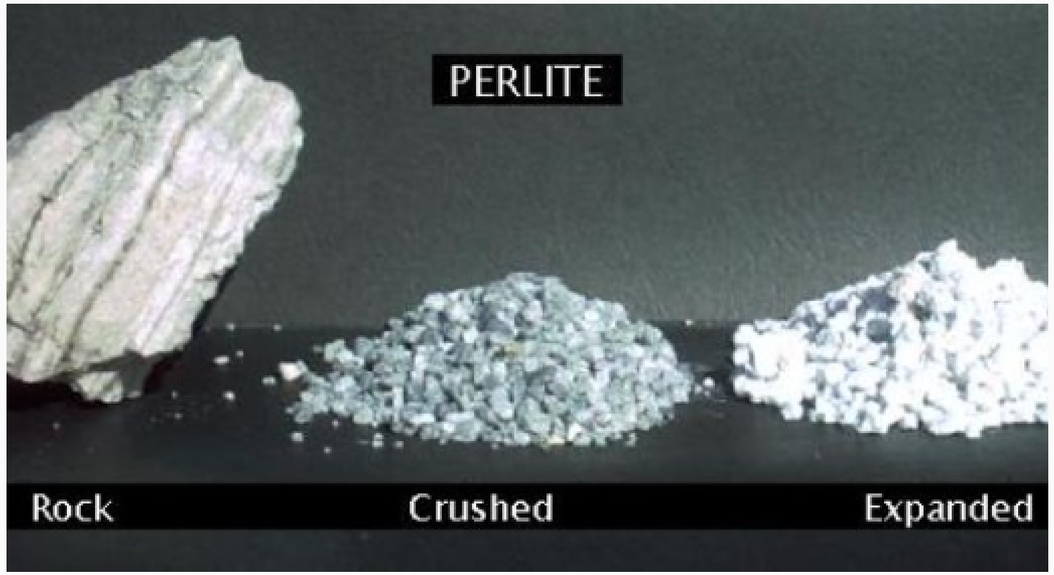
Cons:

- Harmful to health
- Production process is not environmental

SOURCE: APPLIED PLANT PHYSIOLOGY; PROF. TANYA M. QUIST; SCHOOL OF PLANT SCIENCES; U OF A

Growing Media

PERLITE



- Chemically inert (pH 7.0-8.5)
- Low CEC and WHC
- High air porosity
- Accumulation of fluoride ions (F-)

Composition:

- Highly dense aluminum silicate formed from the rapid cooling of volcanic magma. High-temperature processing allows it to expand and form lightweight particles.

Pros:

- Lightweight
- High oxygen retention level

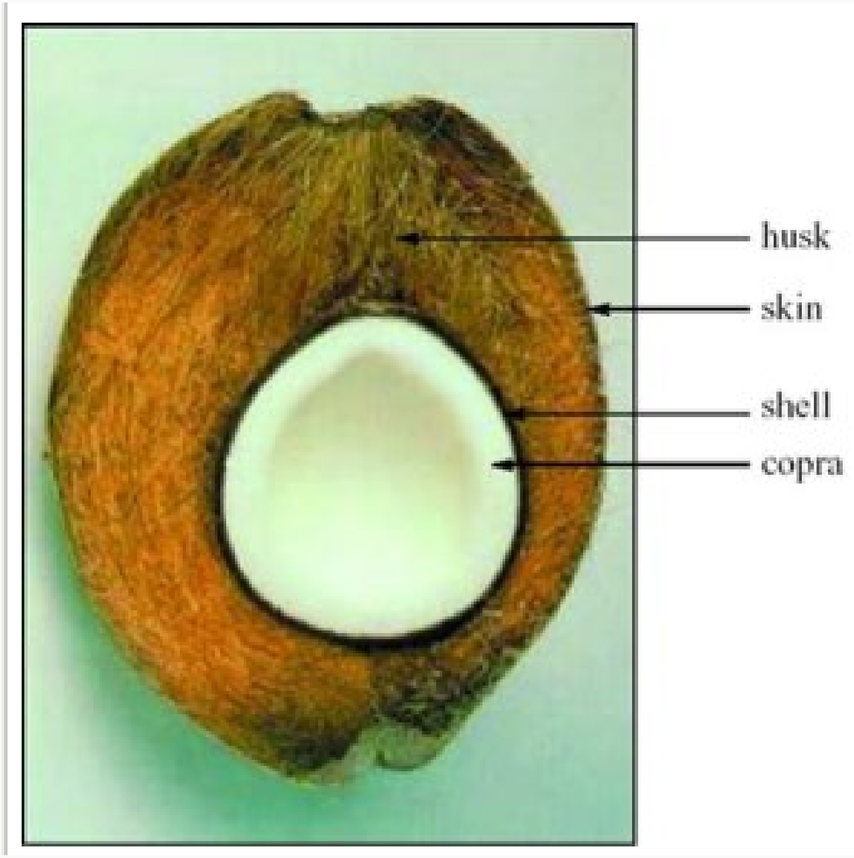
Cons:

- Too lightweight for some systems
- Strip-mined (environmental concerns)
- Potential particle inhalation danger

SOURCE: APPLIED PLANT PHYSIOLOGY; PROF. TANYA M. QUIST; SCHOOL OF PLANT SCIENCES; U OF A

Growing Media

COCONUT COIR



Composition:

- Compressed coconut husk

Pros:

- Inexpensive

Cons:

- High water holding capacity and may drown plants

Physical and chemical properties vary depending on the source:

- High initial salts (EC)
- Low porosity

SOURCE: APPLIED PLANT PHYSIOLOGY; PROF. TANYA M. QUIST; SCHOOL OF PLANT SCIENCES; U OF A

Growing Medias

SOILLESS AGGREGATES: A SOLID MATERIAL OR MATRIX

Rockwool

Oasis Cubes

Perlite

Vermicullite

Coconut Coir

Peat

Expanded Clay
(Hydroton)

Expanded Glass
(Growstones)

Compost

Growing Systems

Classified by growing media

Aggregate Culture: Roots grow into a soilless medium and are irrigated with a complete nutrient solution

Bag Culture

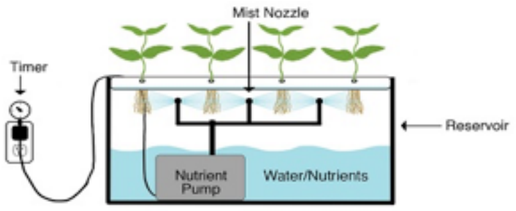
Trough or Raised Bed

Growing Towers

Dutch (Bato) Bucket

Liquid Culture- Roots are hanging in the nutrient solution which can either be in the form of a liquid or a mist

Deep Water Culture/ Raft Systems



Aeroponics

Ebb & Flow Tables

Nutrient Film Technique

Growing systems

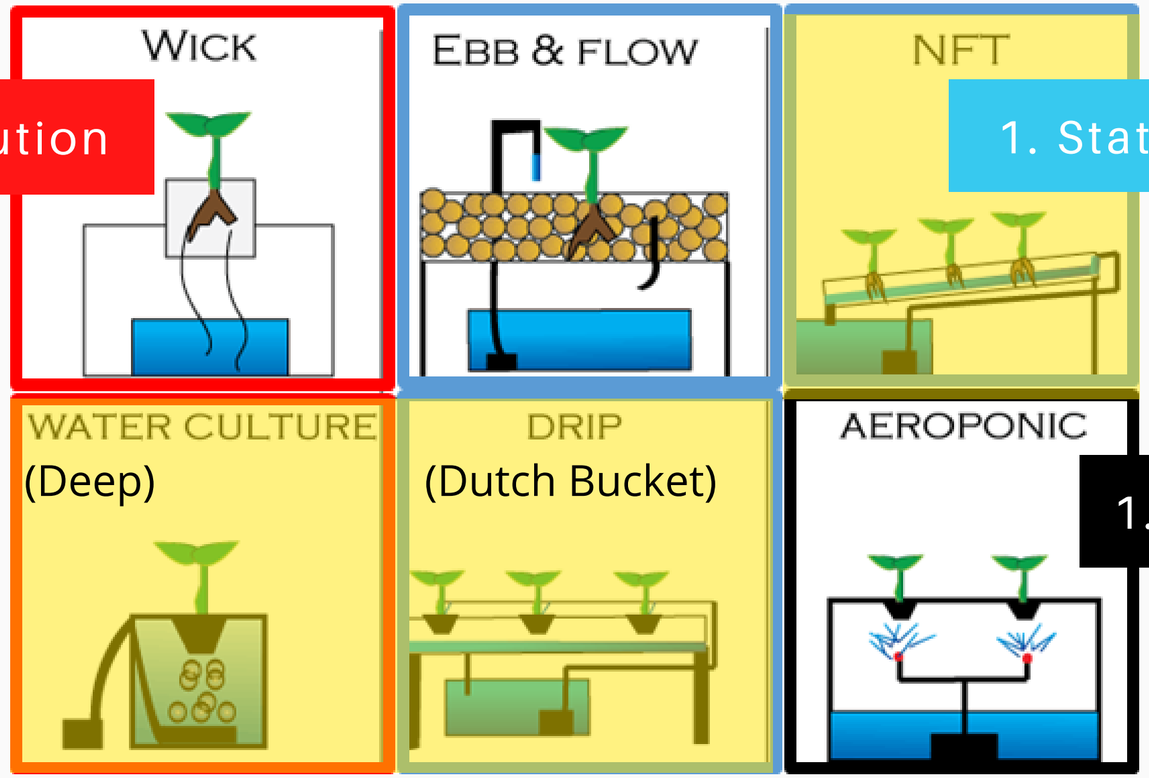
Classified by Irrigation & Fertigation

01	**Static solution**	Plants are floated in a standing solution. Ideal for large experiments, testing many treatments or. production. Requires more intensive adjustment of pH, EC, nutrient levels as these change with time (ie. As plant takes up nutrients. Aeration especially important.
02	**Flowing solution**	Nutrient solution flows over the roots intermittently. Consistent nutrient levels, suited to automation, but risk of desiccation.
03	**Misting systems**	Plants are supported by insertion into holes in a pvc panel, and roots are suspended in mid air in a closed misted environment (mist box). Solution can be recirculated or discharged.

SOURCE: APPLIED PLANT PHYSIOLOGY; PROF. TANYA M. QUIST; SCHOOL OF PLANT SCIENCES; U OF A

6 Hydroponic Growing Systems

Classified by Irrigation and Fertigation



2. Flowing solution

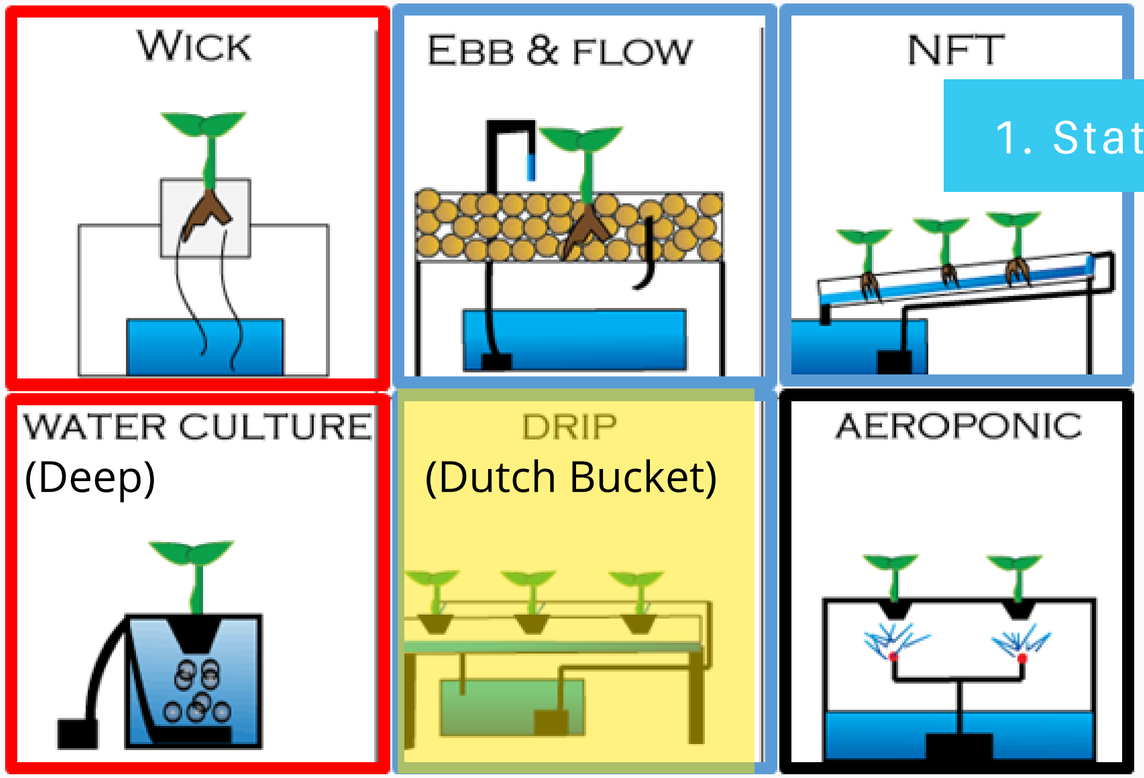
1. Static solution

1. Misting solution

SOURCE: APPLIED PLANT PHYSIOLOGY; PROF. TANYA M. QUIST; SCHOOL OF PLANT SCIENCES; U OF A

6 Hydroponic Growing Systems

Classified by Irrigation and Fertigation

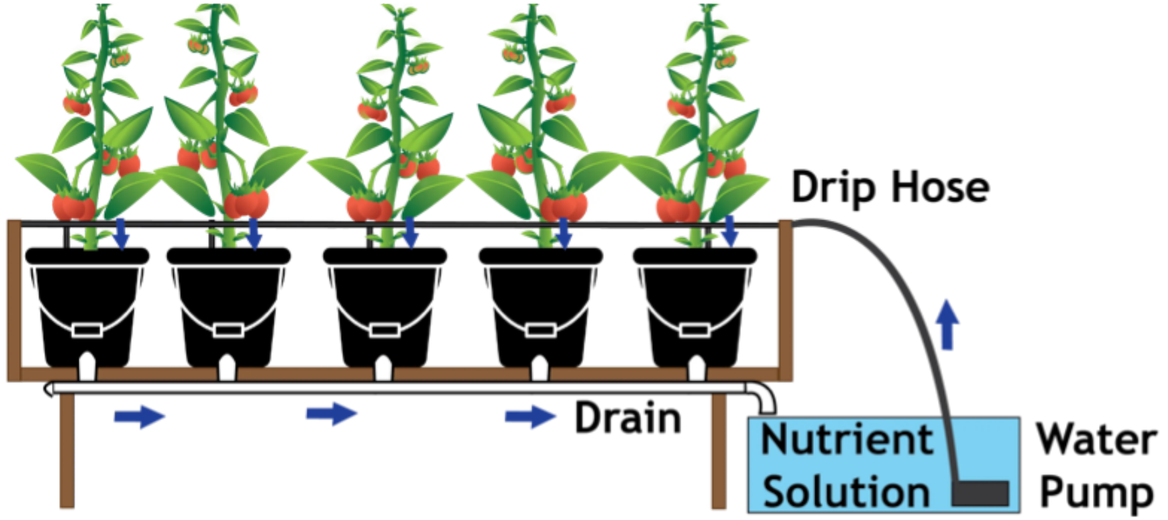


1. Static solution

SOURCE: APPLIED PLANT PHYSIOLOGY; PROF. TANYA M. QUIST; SCHOOL OF PLANT SCIENCES; U OF A

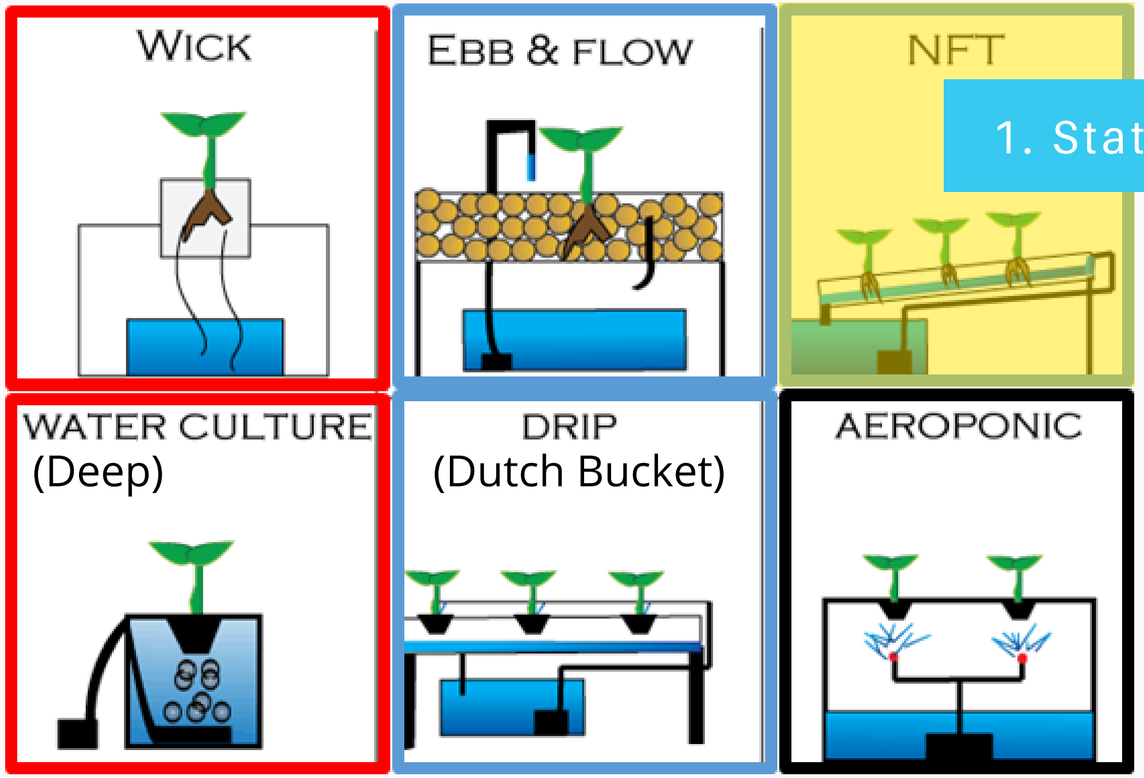
Dutch Bucket (Bato) - *HydroCycle H2-24*

- **What crop?**
  - Tomatoes, cucumber, eggplant, squash, pepper, melons
- **Arrangement and System:**
  - A line of buckets (4' apart) with a plant in each; closed/open system
- **Irrigation:**
  - Top drip system for "fertigation"
  - Needs a timer - Fixed irrigation schedule (ex: 30 minute events 3 times a day)
- **Lighting**
- **Growing media:**
  - Purpose: retain water, allows root air to circulate;
  - Type: perlite (volcanic glass)
- **Structure:**
  - Support by a trellis



6 Hydroponic Growing Systems

Classified by Irrigation and Fertigation

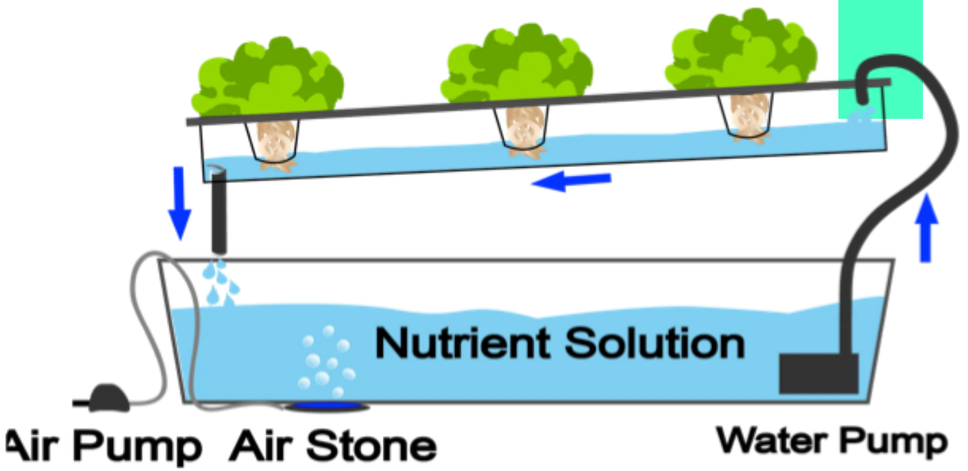


1. Static solution

SOURCE: APPLIED PLANT PHYSIOLOGY; PROF. TANYA M. QUIST; SCHOOL OF PLANT SCIENCES; U OF A

Nutrient Film Technique - *HydroCycle 4" Pro*

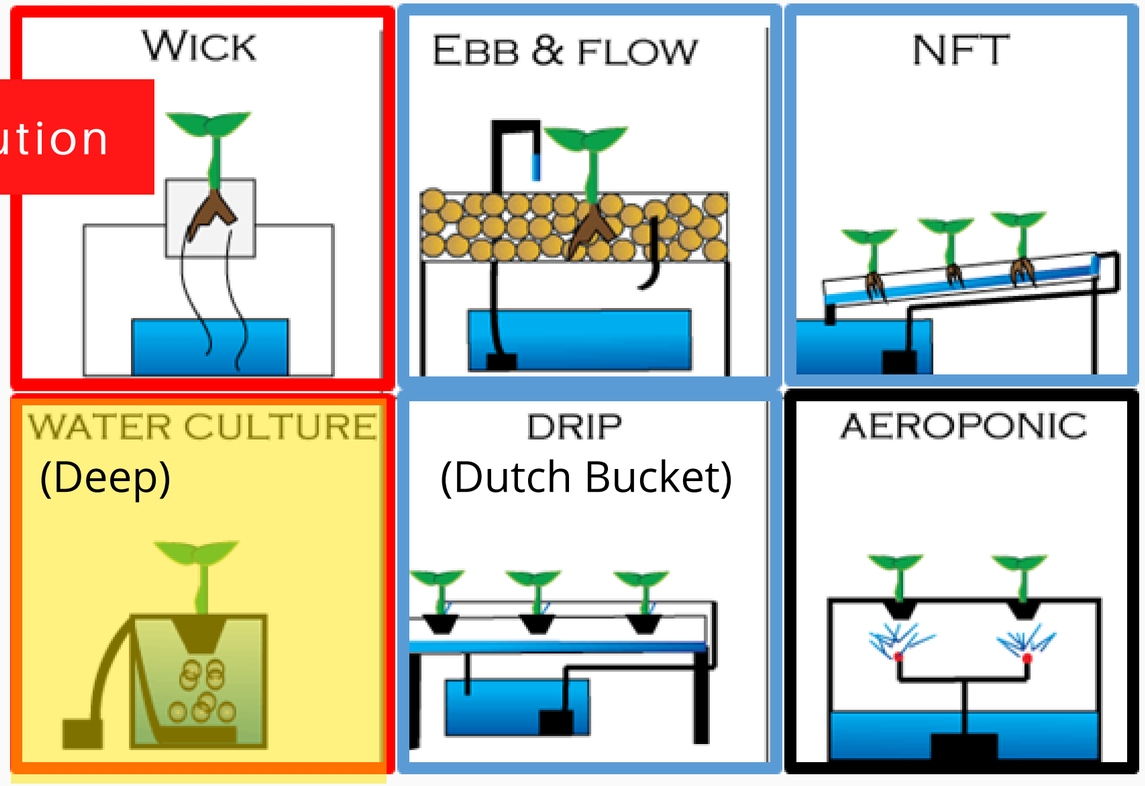
- **Define:**
  - An irrigation technique that grows plants by keeping nutrient solutions on the roots as a thin film without substrate (e.g., soil, soiless aggregate)
- **What crop?**
  - Leafy crops (lettuce, basil, spices)
- **Arrangement and system:**
  - Trough with 0.3-2% slope; Different spacing for different crops/growth stage
  - Needs a pump, no timer
- **Irrigation and fertilization:**
  - Constant flow rate of ¼ -½ gpm
- **Growing media**
  - None



6 Hydroponic Growing Systems

Classified by Irrigation and Fertigation

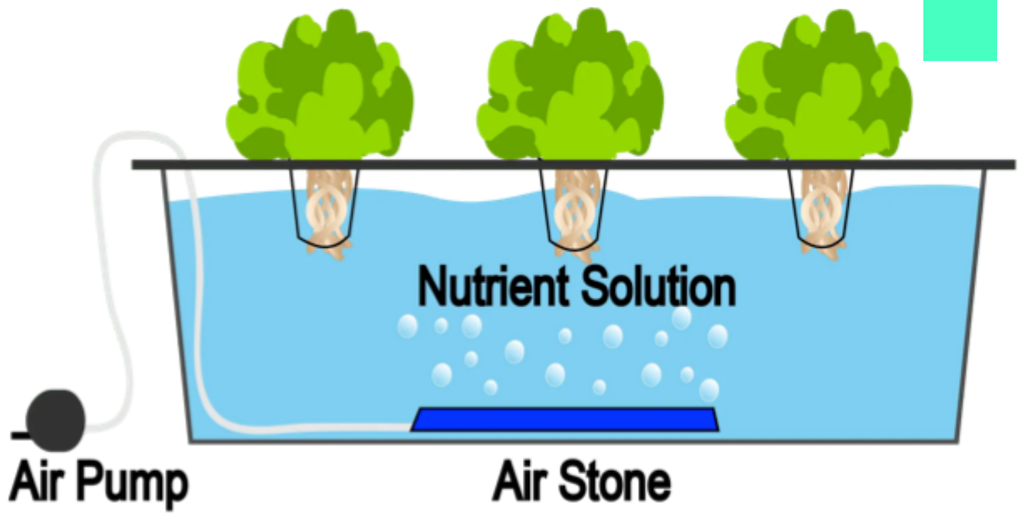
2. Flowing solution



SOURCE: APPLIED PLANT PHYSIOLOGY; PROF. TANYA M. QUIST; SCHOOL OF PLANT SCIENCES; U OF A

Deep Water Culture (DWC)

- **Define:**
  - An irrigation technique in a liquid/closed system with suspended plants in a nutrient solution with oxygen supplied by an air pump or growing media
- **What crop?**
  - Leafy crops (lettuce, herbs)
- **Arrangement and System:**
  - Sometimes an air pump is used
- **Irrigation and Fertilization:**
  - Can be refilled manually or with pump
- **Growing Media**
  - Possible: perlite, other, or none



Deep Water Culture / Raft System

ROOTS ARE HANGING IN THE NUTRIENT SOLUTION WHICH CAN EITHER BE IN THE FORM OF A LIQUID OR A MIST

Comparisons of Growing Systems

Table 1

System	Advantages	Disadvantages	Common crops
Table tops (wire or gutter) (Drip)	✓ Low cost. ✓ Simple ✓ Knowledge and technical support.	× Wasteful of water and nutrients. × No recirculation. × Environmental impact.	Strawberries Raspberries
Ebb and flow	✓ Adaptable to growing media. ✓ Ability to adjust rooting depth. ✓ Potential for re-circulation.	× Low buffering capacity. × Imprecise nutrient and water delivery. × Risk of water borne disease.	Tomatoes, Cucumbers, Melons, Leafy greens.
Deep water culture (Inc. aquaponics)	✓ Used without growing media. ✓ Simple to operate. ✓ Large buffering capacity	× Low potential for recirculation. × Prone to water borne diseases. × Wasteful of water and nutrients.	Lettuce, salad greens, leafy vegetables.
Nutrient film technique	✓ No growing media required. ✓ Water and nutrient efficient. ✓ Well suited to re-circulation. ✓ Good oxygenation.	× Not as suitable for long season crops. × Low buffering capacity. × Costly to set up. × Technically challenging.	Watercress, leafy herbs, leafy salads.
Aeroponics	✓ High precision. ✓ Nutrient and water efficient. ✓ Highest root zone oxygenation.	× Near zero buffering capacity. × High technical skill × Higher cost of setup.	Potentially any, herbs and leafy salads, suitable for delicate crops.

GROWING WITHOUT SOIL; WOOTTON-BEARD, PETER; ABERYSTWYTH UNIVERSITY (2019)

Hydroponics & Traditional Cultivation

Reasons:

1. Earlier yield
2. Higher quality
3. Vining growth habitat maximizes the vertical space of a tunnel
4. Fast turn-around allows for multiple plantings per year or *relay cropping* with cool-season crops

Navajo Cushaw Squash

Navajo Yellow Mellon

Navajo Robin's Egg Corn

Breakout & Jamboard [slide 3]

Hydroponic Nutrient Solutions

DEFINITIONS

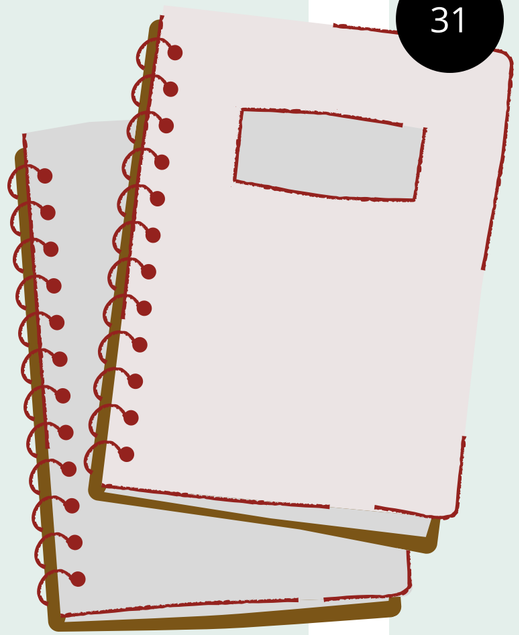
- **Irrigation** = supplying water to plants using ditches, pipes/tubing
- **Fertilizer** = Inorganic "salts" containing the macro/micro elements
  - Organic compounds containing these elements: manure, fish emulsion, bat guano, earthworm castings
- **Fertigation** = use of fertilizers (proper concentrations, pH) for EVERY irrigation cycle
- **Nutrient solution recipe** = list of compounds + amounts required
  - Can be the final concentrations (ppm, mMol, etc.)
  - Can be actual amounts (Kg/tank, ml/liter, g/liter, etc.)

Hydroponic Nutrient Solutions

A complete nutrient solution contains:

- All 16 elements required for plant growth
- Contains the needed amounts of each element for the specific crop being grown

Glossary



- Hydroponics (Kumari et al., 2018)
  - *https://www.phytojournal.com/archives/2018/vol7issue1S/PartAB/SP-7-1-588.pdf*
- Tollefson, S., PLS 217 lecture slides, University of Arizona (2019) [Powerpoint]
- Ifugao
  - *https://whc.unesco.org/en/list/722*
- Growing Media
  - *https://www.epicgardening.com/hydroponic-growing-media/*
  - *Applied Plant Physiology; Prof. Tanya M. Quist; School of Plant Sciences; University of Arizona [Powerpoint]*
- Growing Systems
  - *https://pure.aber.ac.uk/portal/files/30769801/technical_article_hydroponics_final.pdf*
  - *Applied Plant Physiology ... [Powerpoint]*

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RESEARCH, INNOVATION & IMPACT
Arizona Institutes for Resilience

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