THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

Hydroponics & Controlled Environment Agriculture (CEA)

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The Ohio State University

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Controlled Environment Plant Physiology & Technology Lab
(*The Kubota Lab*)

Our Mission

To serve for science-based technology development in the area of controlled environment agriculture (CEA).

To translate scientific understanding and discoveries into innovative applications.

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Controlled Environment Agriculture

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Controlled Environment Agriculture

- High yield
- High quality
- Minimum resource use (water, pesticide, and fertilizer)
- Year-round production (Year-round employment)
- Ergonomic improvement
- Various technology levels
  - Low tech (high tunnels, soil)
  - High tech (computer control, automation, soilless/hydroponics)

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Photo by Merle Jensen

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Annual yield comparison

- Tomato
  - Florida open-field fresh tomato average = 3.2 kg/m^2 (950 million pounds out of 33000 harvested acres in 2015) (0.7 lb/ft^2)
  - Greenhouse benchmark yield = 50-60 kg/m^2 (various sources) (10-12 lb/ft^2)
  - Greenhouse record yield = 100 kg/m^2 (Village Farms, USA/Canada) (20 lb/ft^2)

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Water use comparison
WUE – Water Use Efficiency (kg/m^3)

- California open-field tomato 10-12 kg/m^3 with flood irrigation; 19-25 kg/m^3 with drip irrigation (San Joaquin Valley data)
- Greenhouse tomato 30-66 kg/m^3 with recirculated irrigation system (reported in the Netherlands and Spain).

Source: Sabeh et al. (2011, Transaction of ASABE)

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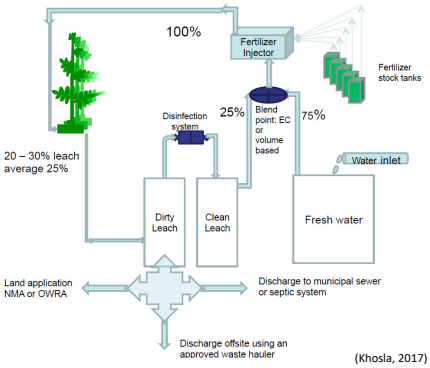
Recirculation of nutrient solution in tomato, cucumber, and pepper crops (high-wire crops)



(Khosla, 2017)

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Intermission for questions

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What do plants need?

Aerial zone (where leaves, stems and fruits are)
- Light
- Good temperature
- CO_2
- Good humidity
- Good air circulation

Root zone
- Water
- Nutrients
- O_2

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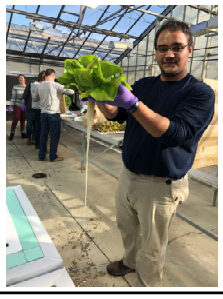
Do you need soil for growing plants?



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Can plants grow without sunlight?

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What is hydroponics?

- Growing method without using soil (AKA soilless culture)
- Dilute nutrient solution provides all micro and macro elements (13) needed by the plants.
- In Europe and Asia, hydroponics strictly refers to water culture (without using substrate).
- In North America, hydroponics has broader definition including aggregate/substrate based **soilless culture**.

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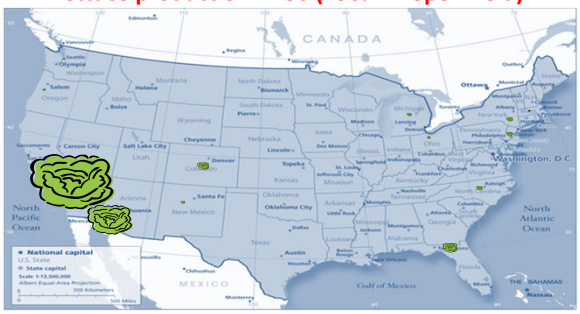
Lettuce production in US (>90% in open field)



USDA Census (2007)

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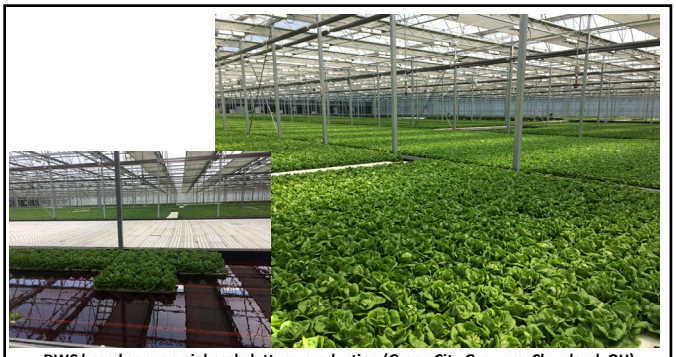

DWC based commercial-scale lettuce production (Green City Growers, Cleveland, OH)

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Gotham Greens, NYC

Great Lake Growers, OH

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Intermission for questions

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20 ha (50 acres) greenhouse in Port Augusta, Australia
- Solar powered
- Use of seawater instead of fresh water

www.sundropfarms.com
https://www.youtube.com/watch?v=rRNy89j6wMc

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VIGEO Gardens (Akron, OH)

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AeroFarms (Newark, NJ)

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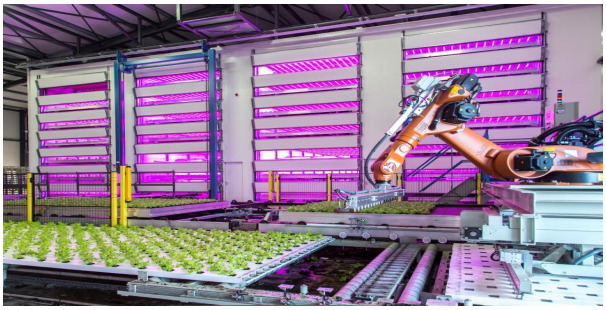
Lettuce seedling production in the Netherlands (Photo credit: Philips Lighting)

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CEA = Controlled Environment Agriculture

Commercial CEA food crop farms in OH

Vine crops (examples)

- Nature Fresh (45 acres, Delta, OH) – to expand to 180 acres
- Mucci Farms (24 acres, Huron, OH) – to expand to 60 acres
- Golden Fresh Farms (20 acres, Wapakoneta, OH) – to expand to 200 acres

Leafy greens (examples)

- Green City Growers Coop. (Cleveland, OH)
- Great Lakes Growers (Burton, OH)
- BrightFarms (Wilmington, OH)
- Old Souls (Saint Paris, OH)
- Chef's Garden (Huron, OH)
- Buckeye Fresh (Medina, OH)
- 80 Acres (Cincinnati, OH)
- Vigeo Gardens (Akron, OH)

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Is hydroponic vegetable tastier than those grown in soil?


www.washingtonpost.com

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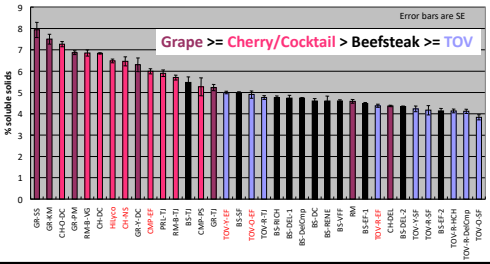
Brix of tomatoes in market: 4% to 8%

The differences are due to genotype, cultural practice, and environment conditions. (Spring 04 survey data)



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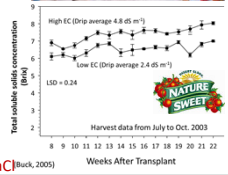
Improving flavor consistency of tomato by managing EC of hydroponic/soilless culture

TOV type tomato under high EC (4.8 dS/m) Brix = 4.8-6.1 Higher lycopene

TOV type tomato under standard low EC (2.4 dS/m) Brix = 3.5-4.8



EC: Electrical conductivity
High EC was achieved by adding NaCl (Buck, 2005)

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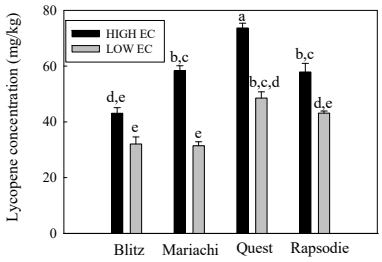

High EC of the nutrient solution can enhance lycopene concentrations of tomato fruit. (Wu et al., 2004)

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Hydroponics systems

- DWC (Deep Water Culture, AKA 'DFT - deep flow technique' or 'floating raft system')
- NFT (Nutrient Film Technique)
- Soil-less culture systems (using substrates)
  - Rockwool
  - Other aggregates (coco coir, perlite, etc.)
- Aeroponics
- Others

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DWC (deep water culture)

Plants are suspended through styrofoam boards which float on the surface of the nutrient solution. Since roots are entirely in the liquid, oxygen must be constantly supplied to the roots by aerating nutrient solution.

(Hydroponic Lettuce Production Guide, Cornell Univ.)

(Photo credit: H. Resh, 2013)

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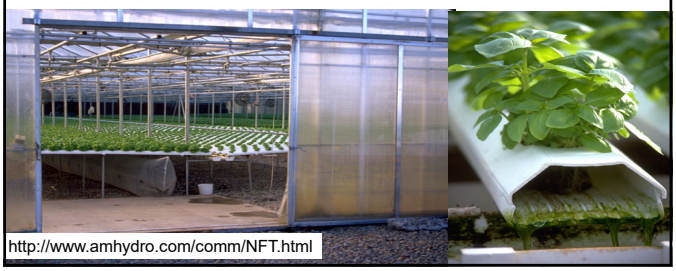
NFT (nutrient film technique)

The roots are hang into a slightly slanted tube or trough. The nutrient solution is pumped to the higher end, flows past the hanging roots and then back to the reservoir.



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Soilless culture with rockwool or other aggregates with drip irrigation

The roots grow into aggregate medium (substrate) such as sand, gravel, Rockwool, perlite, vermiculite, peat moss, foam, coconut coir, etc. and are then irrigated with a complete nutrient solution using drip irrigation.

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High-wire production is a widely used soilless production system for vine crops

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High-wire production for tomato

Photos from Kubota et al. (2018)

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Hydroponic home garden

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Window Farms

Windowfarms.com

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CEA for designing urban food scenes

CEA = Controlled Environment Agriculture

Subway (Tokyo, Japan)

Farmshelf (NYC)

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Container farms (a type of indoor CEA)

CEA = Controlled Environment Agriculture

Local Roots Farms (Los Angeles, CA)

- A fast growing indoor CEA sector.
- Turn-key systems are available.
- Not necessarily the best space use efficiency
- Rental/lease service?

Urban Crop Solutions (US/Belgium)

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Indoor farms (AKA vertical farms)

AeroFrams (Newark, NJ)

VIGEO Gardens (Akron, OH)

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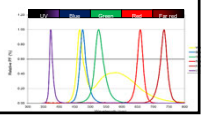
LEDs in Horticulture

- Light emitting diodes (LEDs) were first demonstrated as possible plant lighting source for space farming by Professor Ted Tibbitts (UWI) in 1988.
- High-power blue LEDs in market (since 1993)
- Increasing interest worldwide
- Horticulture LED lamps in market (since 2000)
- Challenges
  - High lamp costs
  - Limited information on optimization (light quality, design and application methods)
- Opportunities
  - Maximizing photosynthesis
  - Photomorphogenesis
  - New applications



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Optimizing plant growth by LED lighting

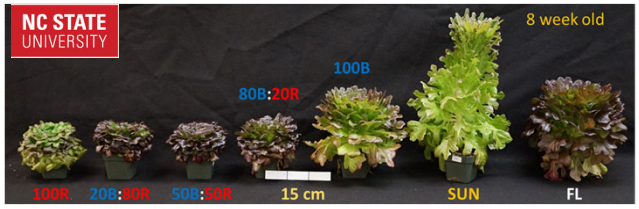

Photo by Ricardo Hernández and Hans Spalholtz

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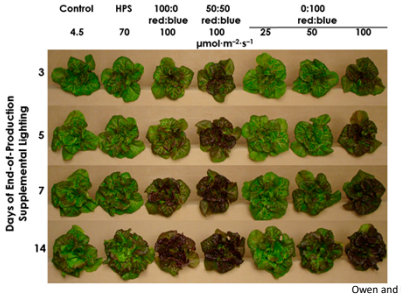
Supplemental LED lighting towards the end of production



Owen and Lopez (2015; HortScience)

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Effects of different supplemental light qualities on baby leaf lettuce growth and nutritional quality (Comparisons with white light control

Parameters \ Supplemental light quality	UV-A	Blue	Green	Red	Far red
Anthocyanins	+ 11%	+ 26%	NS	NS	- 40%
Carotenoids	NS	+ 12%	NS	NS	- 14%
Chlorophyll	NS	NS	NS	NS	- 11%
Ascorbic acid	NS	NS	NS	NS	NS
Phenolics	NS	NS	NS	+ 6%	NS
Biomass	NS	NS	NS	NS	+ 28%

NS = No significant difference by ANOVA at P≤0.05

(Li and Kubota, 2009)

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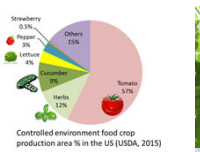
Introducing new crops in US greenhouses



Controlled environment food crop production area % in the US (USDA, 2015)

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Soilless Strawberry Production in Greenhouse

2009-2017 in AZ
2017-Present in OH

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Leafy Green Hydroponics – Developing a New Strategy for Root-Zone Management

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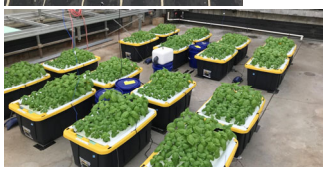
- Basil 'Nufar' & 'Dolce Fresca'
- Spinach 'Corvair'
- pH and micro-nutrient management
  - Possible mitigation of fungal disease without causing plant nutrient disorders
  - Basil plants can tolerate at a pH as low as 4.0!

Dan Gillespie



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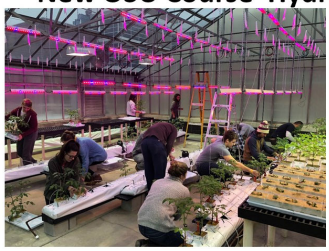
New OSU Course 'Hydroponic Crop Production'



CROPKING · DOSATRON · HORT AMERICAS · oasis GROWER SOLUTIONS · RIJK ZWAAN · RIOCOCO · SPECGRADE LED

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