This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2019-38640-29879 through the North Central Region SARE program under project number YENC20-145. USDA is an equal opportunity employer and service provider. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

1 Sustainable hydroponic crop production

Juan C. Cabrera-Garcia

Field Specialist in Horticulture

Email: jcabrera-garcia@missouri.edu

Telephone: (573)-686-8064

MU Extension
University of Missouri

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

NORTH CENTRAL SARE
Sustainable Agriculture Research & Education

Topics

1. Sustainability
2. Historic overview of hydroponic crop production
3. Hydroponic vs field crop production: Advantages
4. Hydroponic vs field crop production: Disadvantages
5. Hydroponics and the environment
6. Hydroponic systems overview

What is sustainable agriculture?

With sustainable agriculture practices we want to improve the quality of life of farmers and the community by raising profitable crops and livestock while preserving the environment and natural resources.

We want to meet society's food needs and make sure that future generations will have resources to meet their own needs

Pillars of sustainable crop production

Sustainable crop production practices are focused on the 3 Pillars of sustainability:

Profit over the long term

Stewardship of our nation's land, air and water

Quality of life for farmers, ranchers and their communities

How can hydroponics be sustainable

Profitable	Preserving the environment	Quality of life
More produce per square foot	Less land requirement	Natural areas preservation
Lower use of pesticides	Less risk of pesticide drift	Access to safe produce
Efficient water use	Lower use of water	Urban Agriculture
Less fertilizer use	Lower risk of pesticide and fertilizer leaching	Access to fresh local food
		↑Profit=more taxes to serve the community

Topics

1. Sustainability
2. Historic overview of hydroponic crop production
3. Hydroponic vs field crop production: Advantages
4. Hydroponic vs field crop production: Disadvantages
5. Hydroponics and the environment
6. Hydroponic systems overview

What is hydroponics?

Hydro (greek) hudōr = water

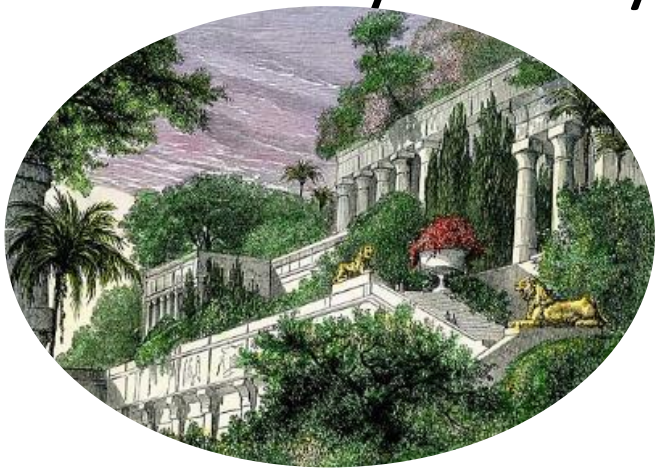
+

ponic (greek) ponos = labor/work

Cropping system that uses an **inert medium** and delivers nutrients in the **nutrient solution**.

It is a **soilless** system.

History of hydroponics



Hanging Gardens of Babylon (605 BC)

Woodward (1699)

Von Sachs and Knop (1860s)

Gericke (1929)

Extension
University of Missouri

Topics

1. Sustainability
2. Historic overview of hydroponic crop production
3. Hydroponic vs field crop production: Advantages
4. Hydroponic vs field crop production: Disadvantages
5. Hydroponics and the environment
6. Hydroponic systems overview

Advantages: No seasonality

Year round production is possible

Advantages: Short crop cycles

Lettuce ready to harvest in 35 to 45 days

Extension
University of Missouri

Compared to more than 70 days in the field

Advantages: High yields

Hydroponic tomato yield

-1975: 89 Ton/acre/year *

-1990: 181 Ton/ acre /year

-2005: 300 Ton/ acre /year

Tomato yield on soil:

-2012: 3.6 – 6.5 Ton/acre/year (NASS, 2012)

*Based on a plant density of 10,000 plants per acre.

Advantages: Food safety

Hydroponic Lettuce

- Lower risk of contamination
- 0 foodborne disease outbreaks from 2014 to 2019

Field Lettuce

- Higher risk of contamination
- 54 foodborne disease outbreaks from 2014 to 2019

Extension
University of Missouri

Resources

Hydroponic Lettuce	Field Lettuce
• Low land requirement	• High land requirement
• 166 Ton/acre/year *	• 15 Ton/acre/year
• Water: 2.4 gal for each pound per year*	• Water: 30 gal for each pound per year
• 11 kWh per pound per year*	• 0.14 kWh per pound per year
• Higher infrastructure costs ($2.5 to $5 per sq ft a year)	• Lower infrastructure costs ($0.2 per sq ft per year)

*Barbosa et al. 2015. *International Journal of Environmental Research and Public Health* **12(6): 6879-6891**

Topics

1. Sustainability
2. Historic overview of hydroponic crop production
3. Hydroponic vs field crop production: Advantages
4. Hydroponic vs field crop production: Disadvantages
5. Hydroponics and the environment
6. Hydroponic systems overview

Disadvantages

- High energy use
- Investment: equipment and greenhouse
- Limited crop diversity

HYDROPONIC LETTUCE

Higher infrastructure costs ($2.5 to $5 per sq ft per year)

- Steep learning curve

FIELD LETTUCE

Lower infrastructure costs ($0.2 per sq ft per year)

Why are yields higher?

Higher yields are a result of the combined effects of:

- Varieties (indeterminate tomato)
- High control of the environment and plant nutrition.
- Efficient use of space (vertical farming)

Why is market demand increasing?

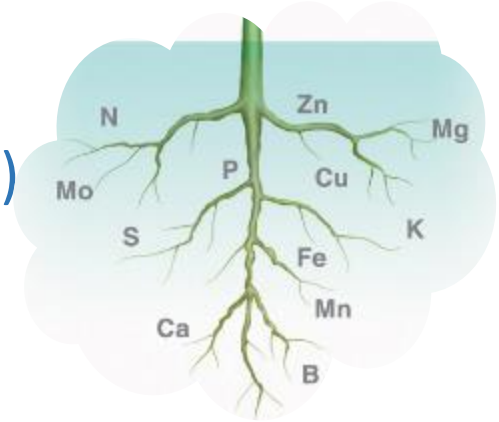
- Consumers want produce that uses less resources (water, soil, and fertilizers) while preserving natural ecosystems and biodiversity.
- Urban areas want fresh local produce.
- People want produce grown with less pesticides.

Topics

1. Sustainability
2. Historic overview of hydroponic crop production
3. Hydroponic vs field crop production: Advantages
4. Hydroponic vs field crop production: Disadvantages
5. Hydroponics and the environment
6. Hydroponic systems overview

Environmental impacts

- Preservation of soils and forests (Higher yields)
- Pollution: lower risk of fertilizer and pesticides runoff and infiltration
- Lower use of resources (water and fertilizers)
- Lower use of pesticides (no need to control weeds)
- Able to supply fresh locally sourced food
- High use of energy (renewable sources)
- High use of plastics



Topics

1. Sustainability
2. Historic overview of hydroponic crop production
3. Hydroponic vs field crop production: Advantages
4. Hydroponic vs field crop production: Disadvantages
5. Hydroponics and the environment
6. Hydroponic systems overview

Types of hydroponic systems

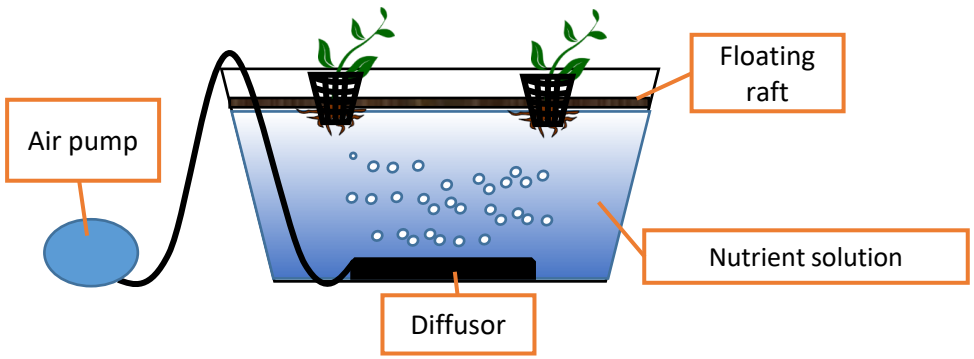
Liquid

Solid

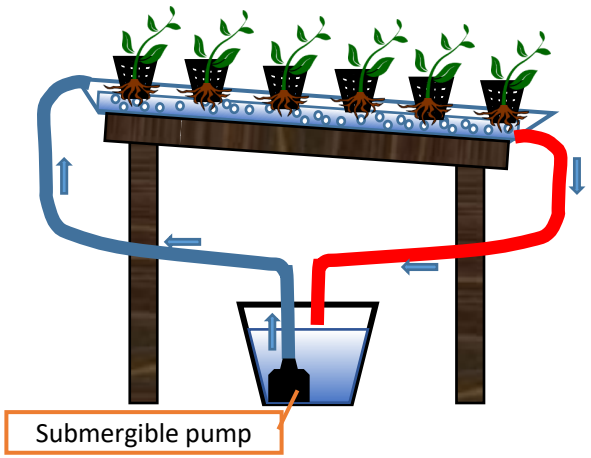
Extension
University of Missouri

Liquid systems

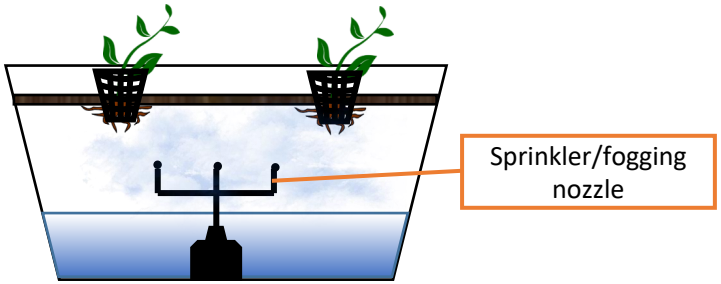
Floating raft/Deep water culture (DWC)



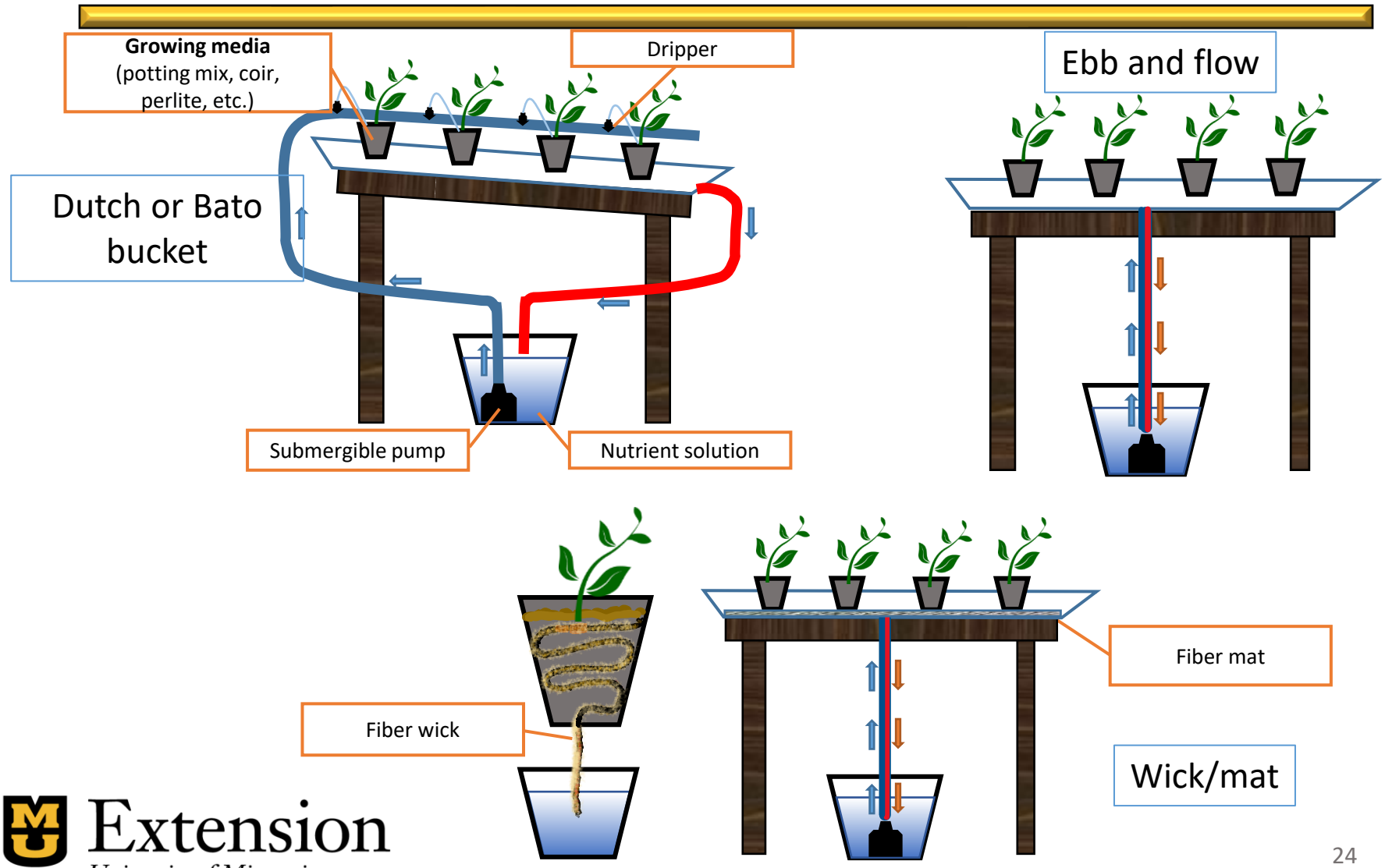
NFT



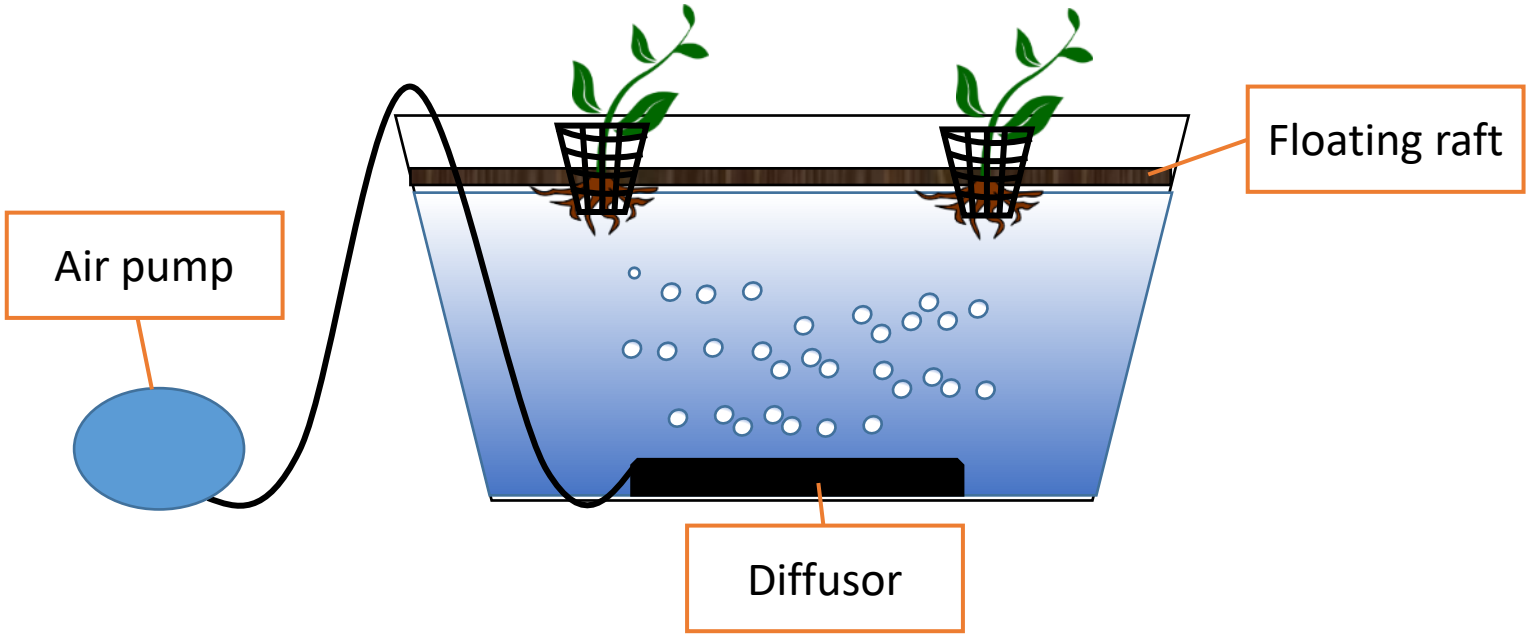
Aeroponic



Solid systems



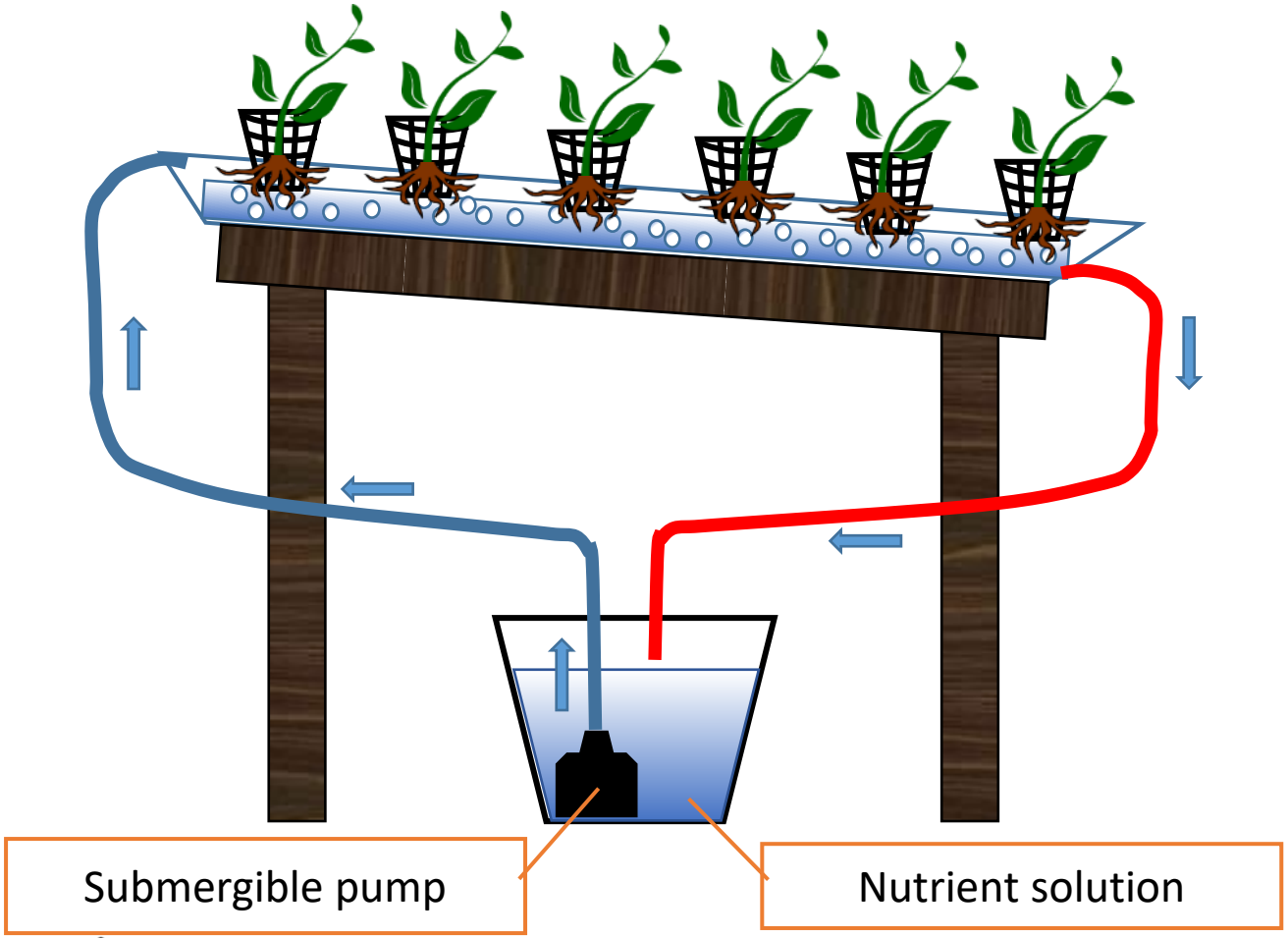
Deep water culture (DWC)



DWC

- ✓ For leafy greens and herbs
- ✓ Plants won't wilt if pump fails
- ✓ Simple construction requires less parts
- × Needs aeration
- × High water and fertilizer use
- × Needs more time and resources to adjust the temperature, pH, and dissolved oxygen

Nutrient Film Technique (NFT)

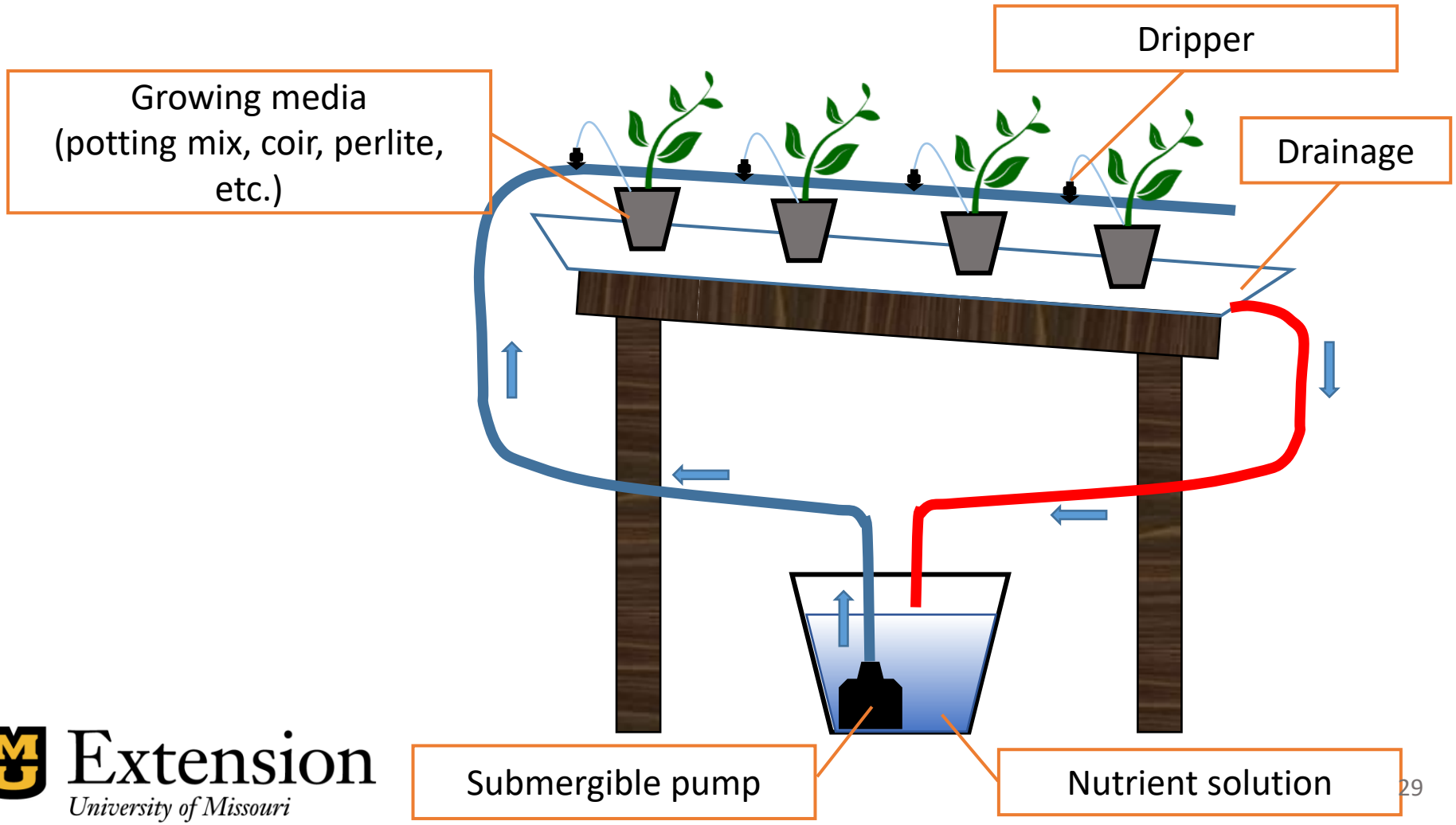


Extension
University of Missouri

NFT

- ✓ For leafy greens and herbs
- ✓ No need for aeration
- ✓ Use less water and fertilizers than DWC
- ✓ Easier to adjust pH and temperature than DWC
- × Susceptible to leakage
- × Driplines can clog
- × Plants wilt immediately if pump fails or if the system clogs

Dutch/Bato bucket



Dutch/Bato bucket

- Ideal for vines and fruiting crops– tomato, cucumber, cantaloupe
- Needs trellis system to guide plant growth and support weight
- The irrigation frequency and nutrient/water retention will depend on the type of **growing media**

Growing media options

Perlite

Coir

Rockwool

Potting mix

Expanded clay pellets

Any material that can be sourced locally?

Affordable
Sustainable
Locally sourced

Gravel

Extension
University of Missouri

Rockwool

☑ Water retention, good aeration, adaptable to several systems, and stable over time

☒ Requires prolonged saturation, difficult to decompose, not organic, and costly

Coconut coir

☑ Retains water and nutrients, good aeration, sustainable, cheap, and compostable

☒ Variable quality (depends on supplier) and not stable over time

Other growing media materials

Perlite

☑ Cheap , aeration

☒ Low water retention, dust

Expanded clay pellets

☑ Reusable, stable over time

☒ Low water retention, $$$, heavy

Gravel

☑ Cheap, stable over time

☒ Low water retention, heavy

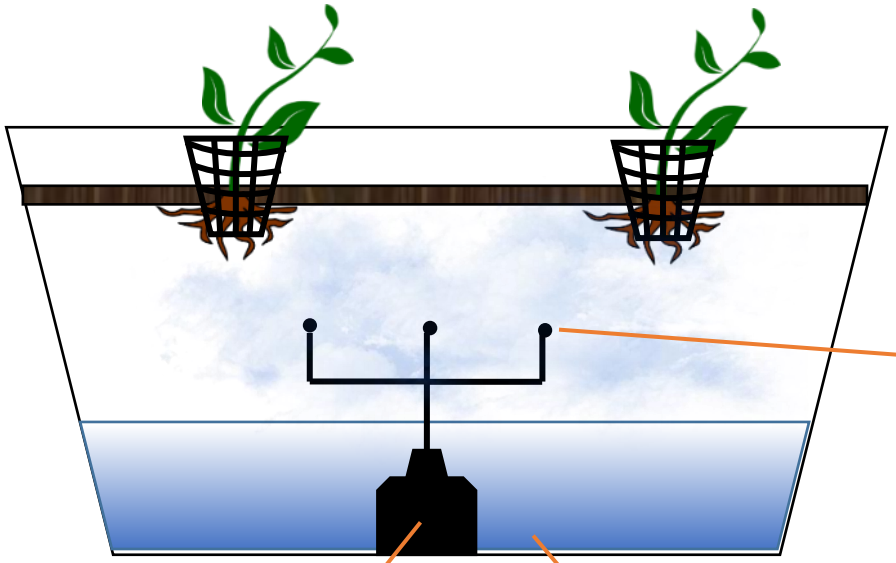
Commercial mixes

Sustainable? (peat)

☑ Retains water and nutrients

☒ pH changes over time (constant monitoring) not stable over time

Aeroponics


Micro sprinkler/fogging nozzle
Submergible pump
Nutrient solution

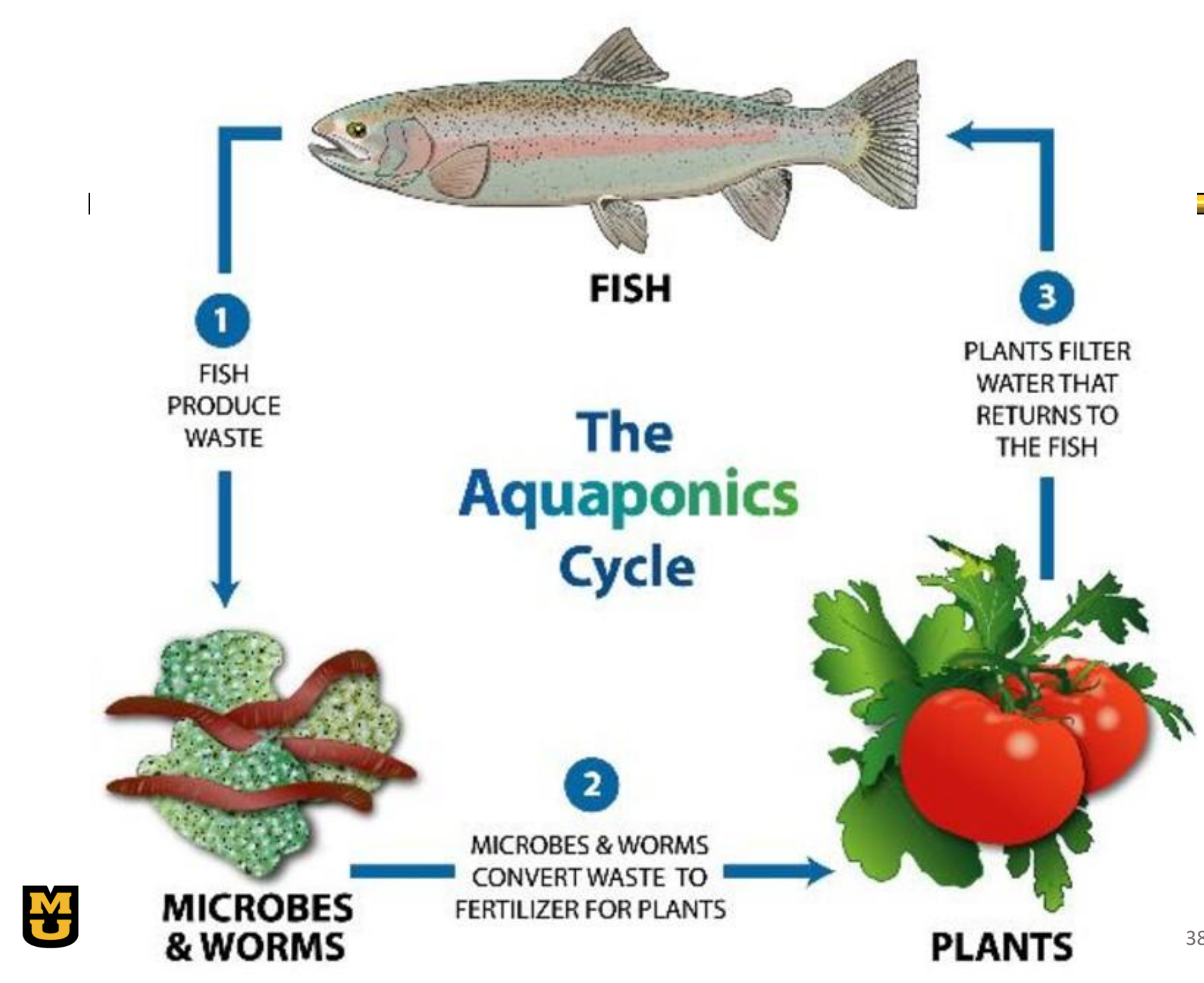
Aeroponics

- ✓ For leafy greens, herbs, and strawberries
- ✓ No need for aeration
- ✓ Requires less water than NFT and DWC
- ✓ Adaptable to many designs
- × Requires good water quality to prevent clogging
- × Plants wilt immediately if pump fails or emitters clog
- × Requires a pressurized irrigation system

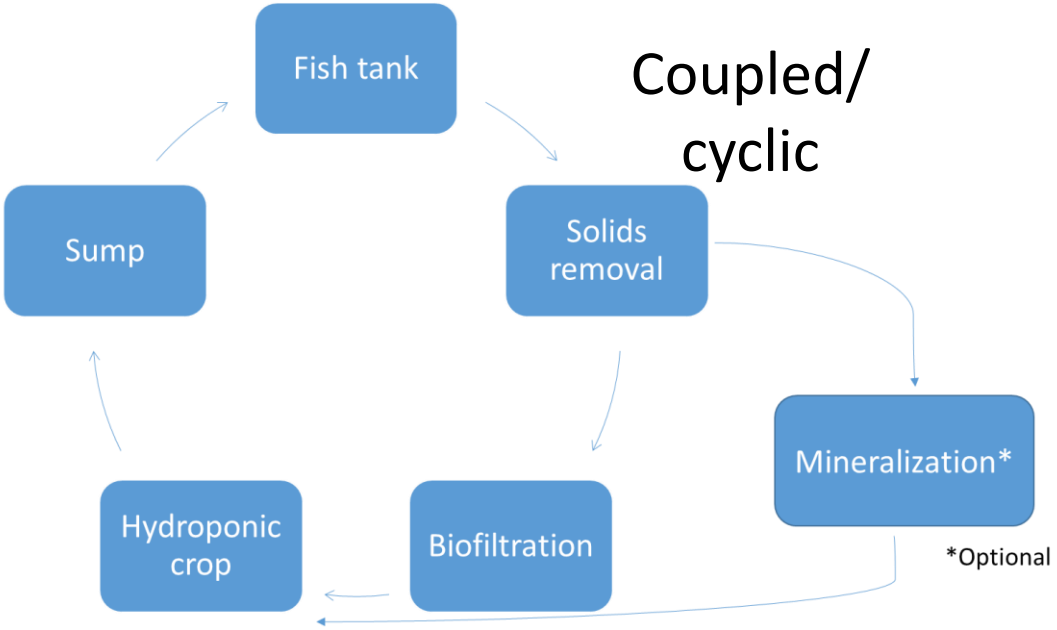


Aquaponics

It’s not easy. The fish residues may not provide all nutrients and there is a lot of solid residues

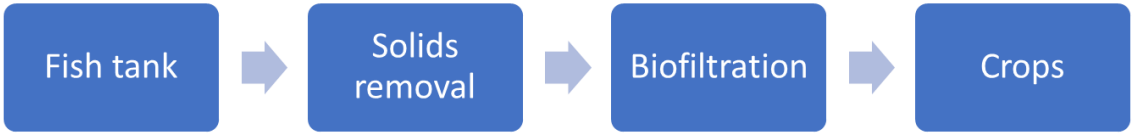

FISH
1
FISH PRODUCE WASTE
3
PLANTS FILTER WATER THAT RETURNS TO THE FISH
The Aquaponics Cycle
2
MICROBES & WORMS CONVERT WASTE TO FERTILIZER FOR PLANTS
MICROBES & WORMS
PLANTS

Aquaponic systems



Coupled/ cyclic

Decoupled/linear



Extension
University of Missouri

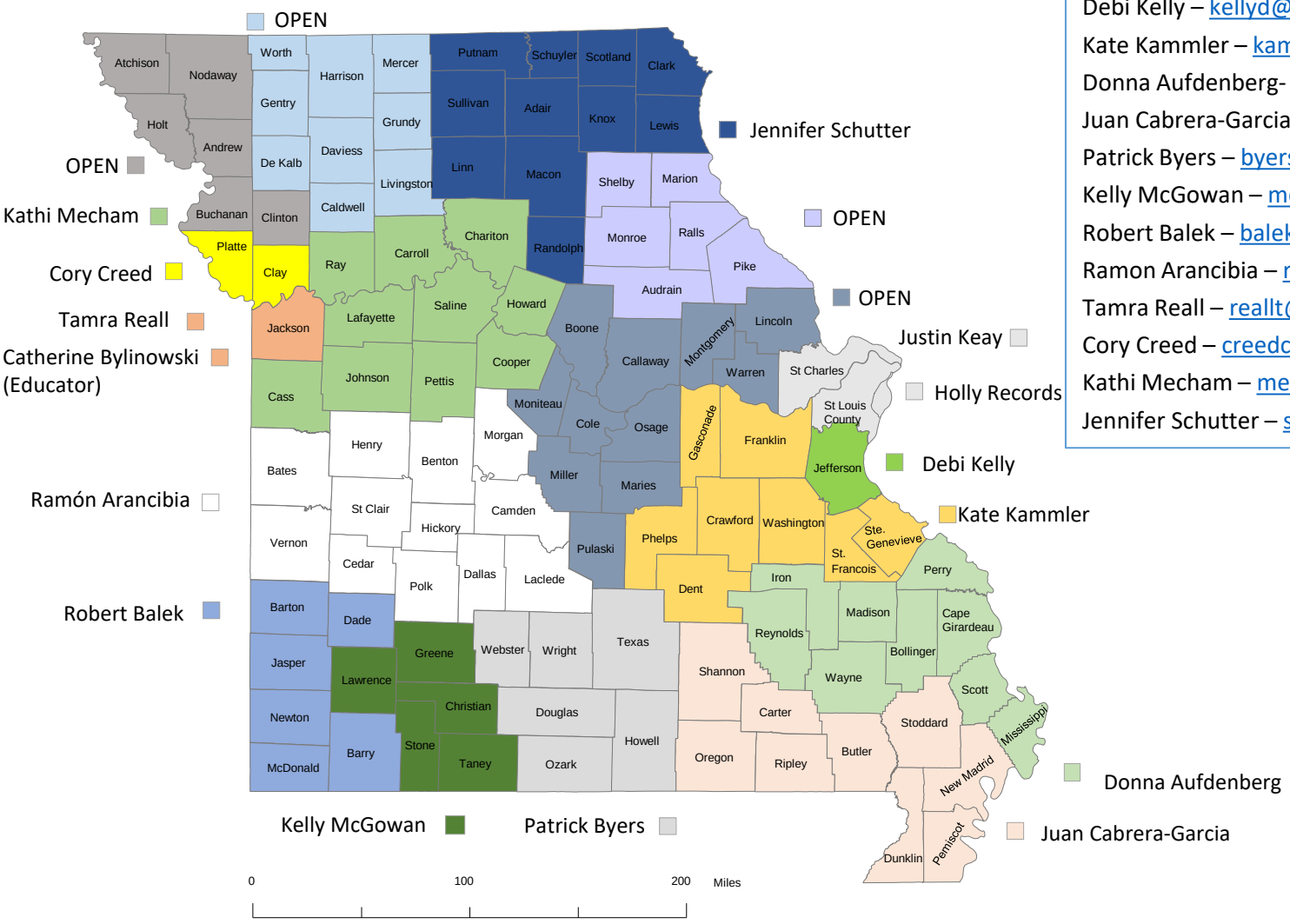
Build your own system

Photo: Wikipedia

Photo: Andrew Reardon

Horticulture Specialists

Justin Keay – Justin.keay@missouri.edu
Debi Kelly – kellyd@missouri.edu
Kate Kammler – kammlerk@missouri.edu
Donna Aufdenberg- aufdenbergd@missouri.edu
Juan Cabrera-Garcia – jcabrera-garcia@missouri.edu
Patrick Byers – byerspl@Missouri.edu
Kelly McGowan – mcgowank@Missouri.edu
Robert Balek – balekr@Missouri.edu
Ramon Arancibia – ramon.arancibia@Missouri.edu
Tamra Reall – reallt@Missouri.edu
Cory Creed – creedca@Missouri.edu
Kathi Mecham – mechamk@Missouri.edu
Jennifer Schutter – schutterjl@Missouri.edu



Extension
University of Missouri

College of Agriculture, Food & Natural Resources
University of Missouri