Crash course on hydroponic tomato cultivation

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Topics

- **Introduction**
  - Sustainability, Advantages, Environmental Impact, Organic hydroponics
- **Hydroponic system for tomatoes**
- **Varieties and production timeline**
- **Production**
  - Seedling production
  - Crop nutrition
  - Pollination
  - Training and pruning
  - Harvest and post-harvest storage
- **Common problems**

What is sustainable agriculture?

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

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

Advantages: No seasonality

Year round production is possible

Advantages: Short crop cycles

Lettuce ready in 35 to 45 days

Compared to 65-70 days in the field

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

https://www.cdc.gov/foodsafety/communication/leafy-greens.html

Advantages: Food access

- **Limited land availability in urban areas**
  - Development is more profitable
  - Contaminated sites
  - Zoning restrictions
- **Food quality: beneficial compounds are lost after harvest**
- **Water use efficiency: Municipal water is expensive**
- **Food deserts in urban areas**

Advantages: High yields

Hydroponic tomato yield

-1975: 89 Ton/acre/year *

-1990: 181 Ton/acre/year

-2005: 300 Ton/acre/year

-Current av: 448 Ton/acre/year

Tomato yield on soil:

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

-15 to 40 Ton/acre/year (reports)

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

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)**

Resources

Hydroponic Lettuce

- Low land requirement
- 166 Ton/acre/year *
- Water: 2.4 gal for each pound per year*
- 11 kWh per pound per year*
- Higher infrastructure costs ($2.5 to $5 per sq ft a year)

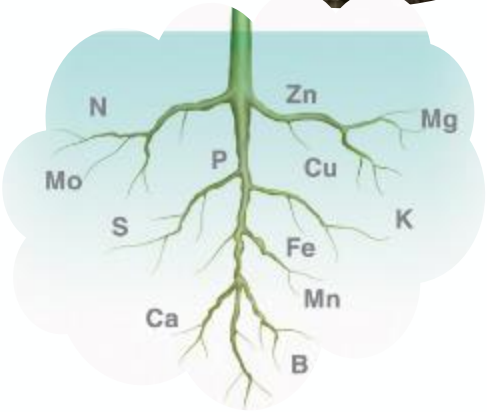
Field Lettuce

- High land requirement
- 15 Ton/acre/year
- Water: 30 gal for each pound per year
- 0.14 kWh per pound per 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**

Environmental impacts

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



Why is market demand increasing?

- Consumers want produce that uses less resources (water, soil, and fertilizers) while preserving natural ecosystems and biodiversity.
- People want produce grown with less pesticides and with high nutritional value.
- Urban areas want fresh local produce.
- Perceptions about hydroponics are evolving

Organic hydroponic debate

- Organic Foods Production Act (OFPA)
  - National Organic Program (NOP)
  - National Organics Standards Board (NOSB)
- Since **1995 NOSB made comments** about organic hydroponic labeling, **but no rule has been made by NOP**
- **2017 NOSB voted to remove aeroponics** from the labeling, but **USDA has yet to act** on this recommendation

Organic hydroponic debate

- **Arguments against organic hydroponics:**
  - They do not build healthy soils
  - They fail to adhere to OFPA's soil fertility requirement
  - They violate OFPA's requirements to improvement of soil quality, management of soil fertility, use of crop rotation practices, conservation of biodiversity, use of other soil management practices, and use of soil samples to measure compliance with OFPA
- **March 19, 2021: court ruled to allow organic certification because the OFPA doesn't specifically prohibit hydroponic operations**

Steps to organic certification

1. Develop organic system plan (OSP): detail how you will comply with regulations and use of approved substances

   https://www.ecfr.gov/current/title-7/part-205/subpart-g
2. Have the OSP reviewed by a *certifying agent* and implement it
3. Get inspected
4. Have the certifying agent review the inspection report
5. Receive a decision from certifier

Find an USDA-accredited certifying agency:

https://www.ams.usda.gov/resources/organic-certifying-agents

Cost share program:

https://www.fsa.usda.gov/programs-and-services/occsp/index

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What is hydroponic?

Crop production system that uses an inert medium and nutrients are provided with a solution.

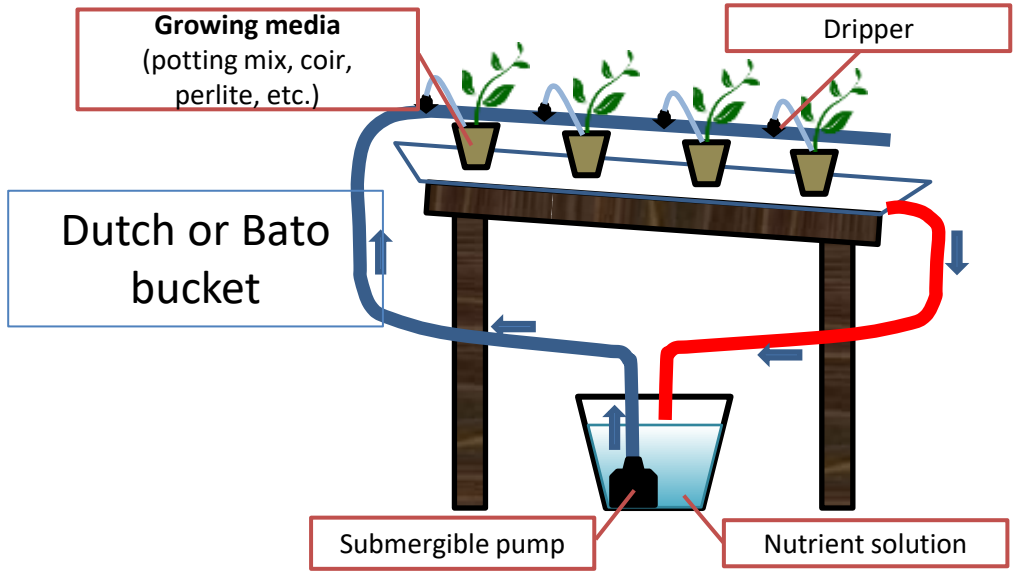
It is a soilless production system.

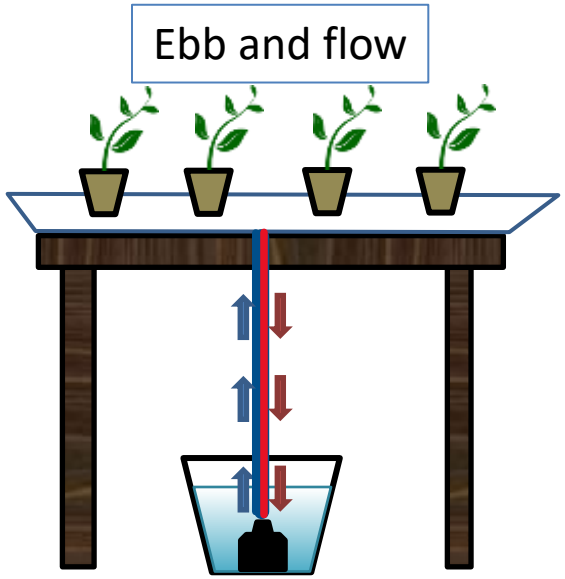
Types of hydroponic systems

Liquid

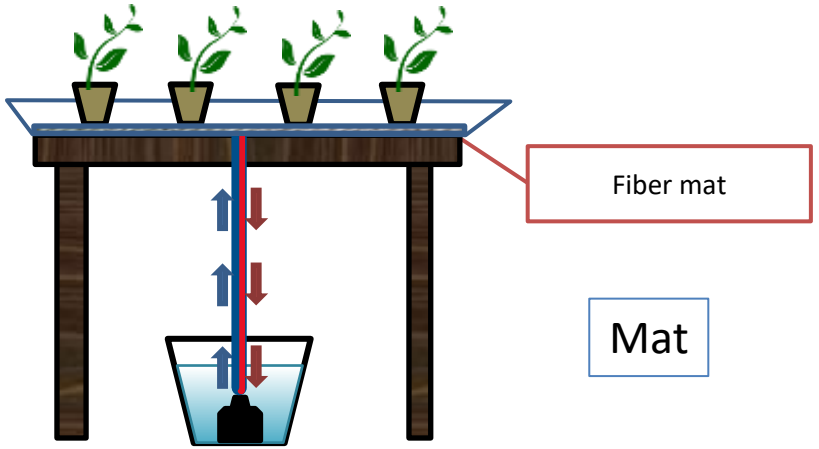
Solid

Systems adequate for vine crops





Plastic pot, Bato bucket, grow bag, or media slabs



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

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

Investment estimates

- Rule of thumb $15 to $30 per sq ft

30’ x 90’	Double layer PE tunnel	Arched polycarbonate	Gothic polycarbonate
	Infrastructure cost $ per sq ft		
Dutch bucket kit	$18.23	$21.76	$29.42
NFT system	$20.75	$24.28	$31.94
DWC	$19.67	$23.20	$30.85
Aquaponic system	$42.02	$45.55	$53.20

- Production costs:

	Tomatoes
Field cost ($/lb)	$0.59
Greenhouse cost ($/lb)	$0.70
Indoor farm cost ($/lb)	$1.85

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Tomato varieties

- **Determinate vs Indeterminate**
- **Heirloom**
  - Pre 1950's
  - Higher retail price, low yields, and susceptible to diseases
- **Size/types:**
  - Slicers: Beefsteak (large) globe (regular)
  - Plum/Roma paste/processing tomato
  - Cherry and grape: small size for fresh consumption
- **Check for disease, insect, and abiotic disorder resistance**

http://www.vegetablemdonline.ppath.cornell.edu/Tables/Tomato_2013.pdf

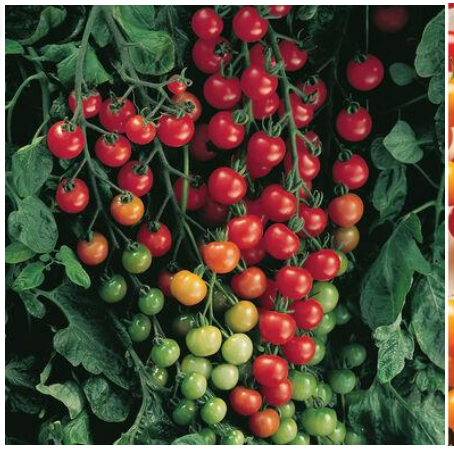
Beefsteak

Slicing

Paste

Cocktail

Grape



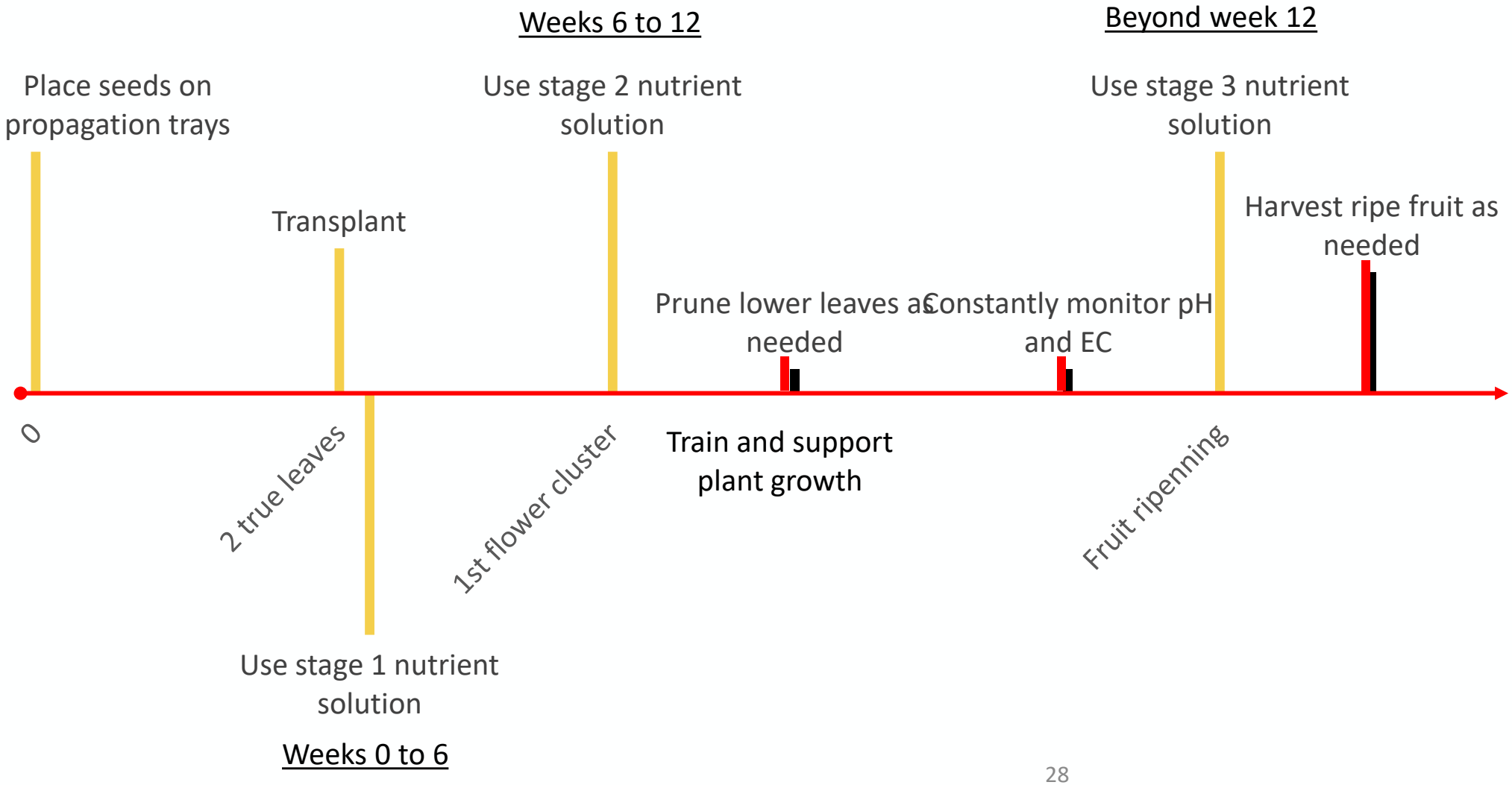
Cherry

Currant

Colors

Photos: Johnny’s Selected Seeds

Hydroponic tomato production timeline



	Month 1				Month 2				Month 3				Month 4				Month 5				Month 6				Month 7				Month 8				Month 9				Month 10				Month 11				Month 12				Month 1 year 2			
	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
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ge 2 nutrient solution									X	X	X	X	X	X																																				
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p and remove debris																																															X	X		

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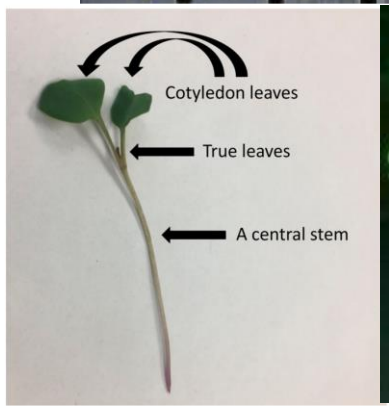
Media for seedling production

Rockwool	Compressed peat or coconut coir pellets	Synthetic materials
  Foto: Grodan.com	 	

Seedling production

1. Saturate the media with water (no fertilizers)
2. Place the seeds on the media
3. Cover the seeds for 24-48 hours (or place in a dark room)
4. Remove the cover and place seeds under light and keep them moist using a 75 ppm N nutrient solution
5. Seedlings will be ready when the first pair of true leaves are fully expanded
6. Place the seedling in the system



System prep before transplant

- **Clean debris from previous crop**
- **Inspect system for leaks and broken parts**
- **Make sure you have all meters and materials in stock**
  - Fertilizers
  - Acid and base (adjust pH)
  - Conductivity and pH meters (with calibrating solutions)
  - Pruning shears, trellis, clips, sticky traps, etc.
- **Mix fertilizer with water then adjust pH**

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Vine crop requirements

(ppm)	Tomato	Cucumber
N	125-225	160-210
NH_4 (% Total N)	5-10	7-14
P	40-60	40-60
K	200-350	325-370
Ca	120-180	190-210
S	40-140	120-140
Mg	30-60	60-75
Fe	3-7	1-2
K/N Proportion	1:1 to 1.7:1	1.8:1 to2.1:1
EC	1.5-3.5	1.5-3.0

Courtesy: Richard McAvoy, Univ. of Connecticut

1 ppm = 1 mg in 1 liter

Tomato nutrient requirement by growth stage

Growth stage	K:N
Vegetative stage (before first flower)	1:1
1st to 4th cluster	1.5:1
Ripe fruit	1.7:1

To promote vegetative growth in any stage by increasing the amount of ammonium nitrogen (NH_4).

Courtesy: Richard McAvoy Univ. of Connecticut

Tomato Stage 1

- Use until you see the first cluster of flowers (approx. 6 weeks)
- For every 10 gallons add:
  - 0.8 oz (23 grams) of 5-12-26
  - 1 oz (29 grams) of 15.5-0-0
  - 0.4 oz (11 grams) of Epsom salts
- Dilute fertilizers separately
- Measure pH and EC
- Adjust pH 5.5 to 6.5

Element	Required ppm	Provided by fertilizers
Total N	145	150
P	47	72
K	145	156
Ca	144	147
Mg	60	65
S	10	90
B	0.4	0.30
Cu	0.05	0.09
Fe	2	2
Mn	0.55	0.30
Mo	0.05	0.11
Zn	0.33	0.09
K:N ratio	1.0	1.04

Tomato Stage 2

- Use until you see the fourth cluster of flowers (weeks 6 to 12)
- For every 10 gallons add:
  - 1.5 oz (43 grams) of 5-12-26
  - 1.2 oz (34 grams) of 15.5-0-0
- Dilute fertilizers separately
- Measure pH and EC
- Adjust pH to 5.5 to 6.5

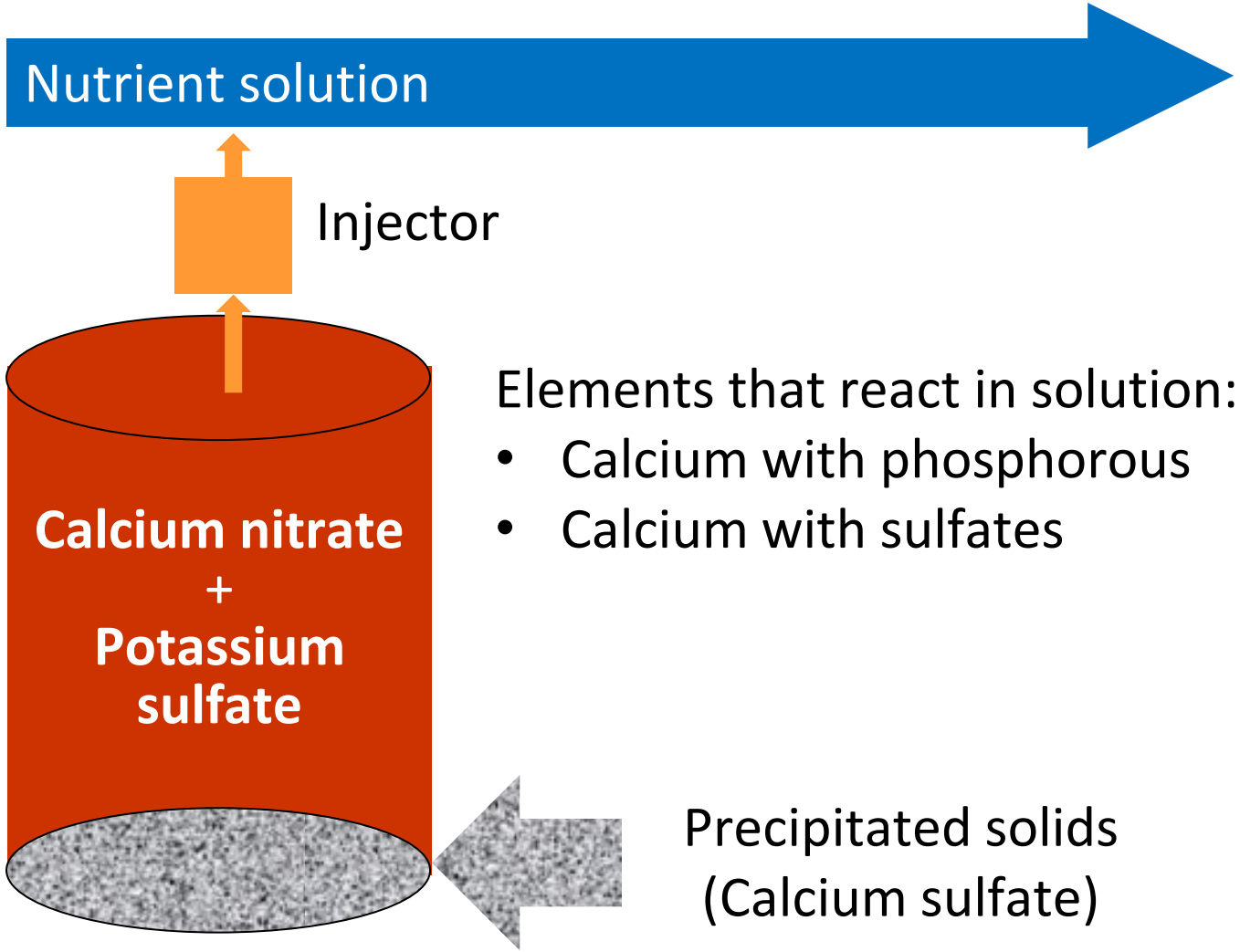
Element	Required ppm	Provided by fertilizers
Total N	195	195
P	47	137
K	300	300
Ca	160	168
Mg	60	69
S	10	98
B	0.4	0.58
Cu	0.05	0.17
Fe	2	3. 5
Mn	0.55	0.58
Mo	0.05	0.22
Zn	0.33	0.17
K:N ratio	1.54	1.54

Tomato Stage 3

- Use when you see the fruits ripening (plants older than 12 weeks)
- For every 10 gallons add:
  - 2 oz (57 grams) of 5-12-26
  - 1.4 oz (39 grams) of 15.5-0-0
- Dilute fertilizers separately
- Measure pH and EC
- Adjust pH 5.5 to 6.5

Element	Required ppm	Provided by fertilizers
Total N	205	240
P	47	186
K	350	403
Ca	200	200
Mg	60	93
S	10	132
B	0.4	0.8
Cu	0.05	0.2
Fe	2	4.7
Mn	0.55	0.8
Mo	0.05	0.3
Zn	0.33	0.2
K:N ratio	1.7	1.68

Fertilizer Incompatibility: Salt reaction

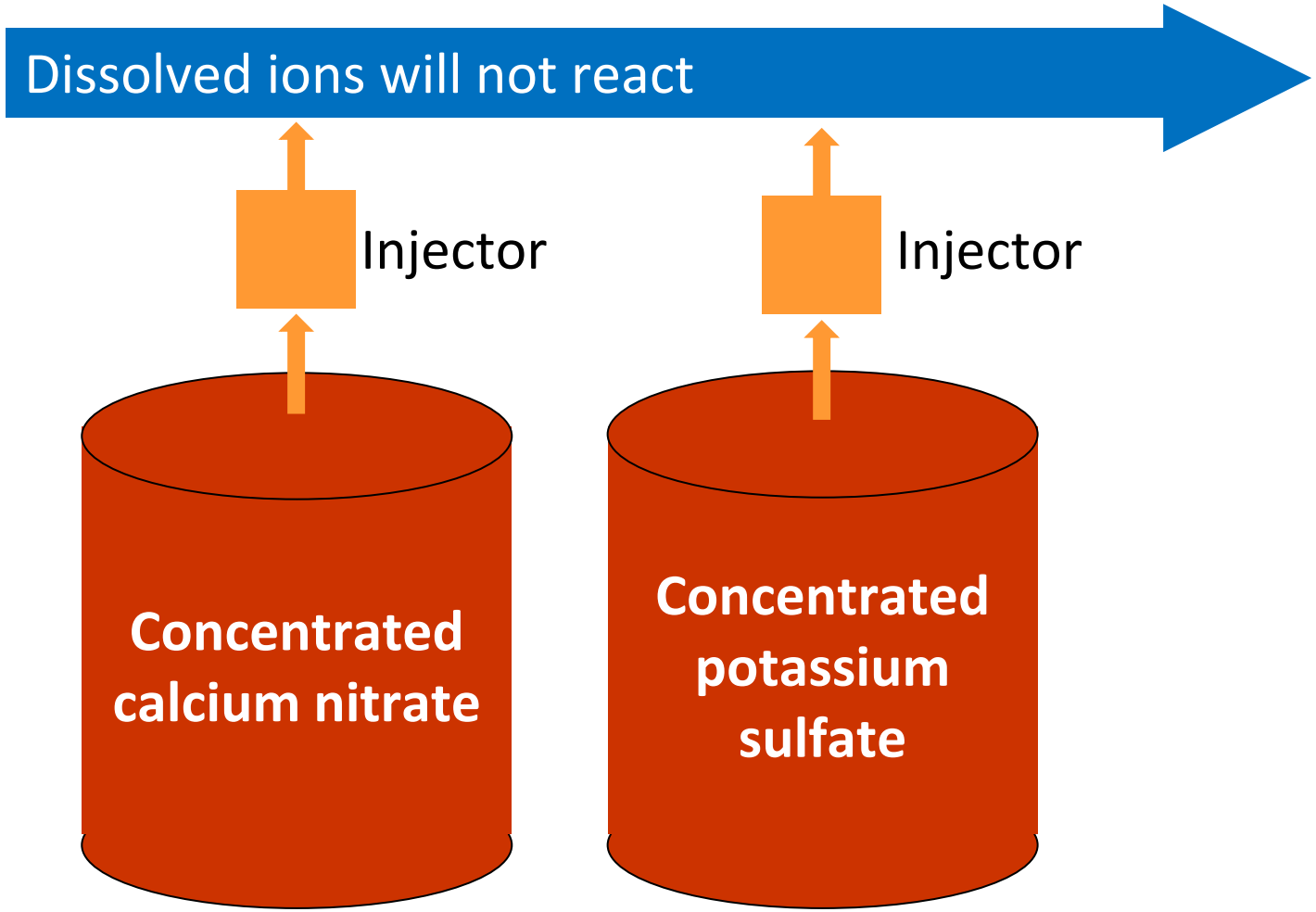


Elements that react in solution:

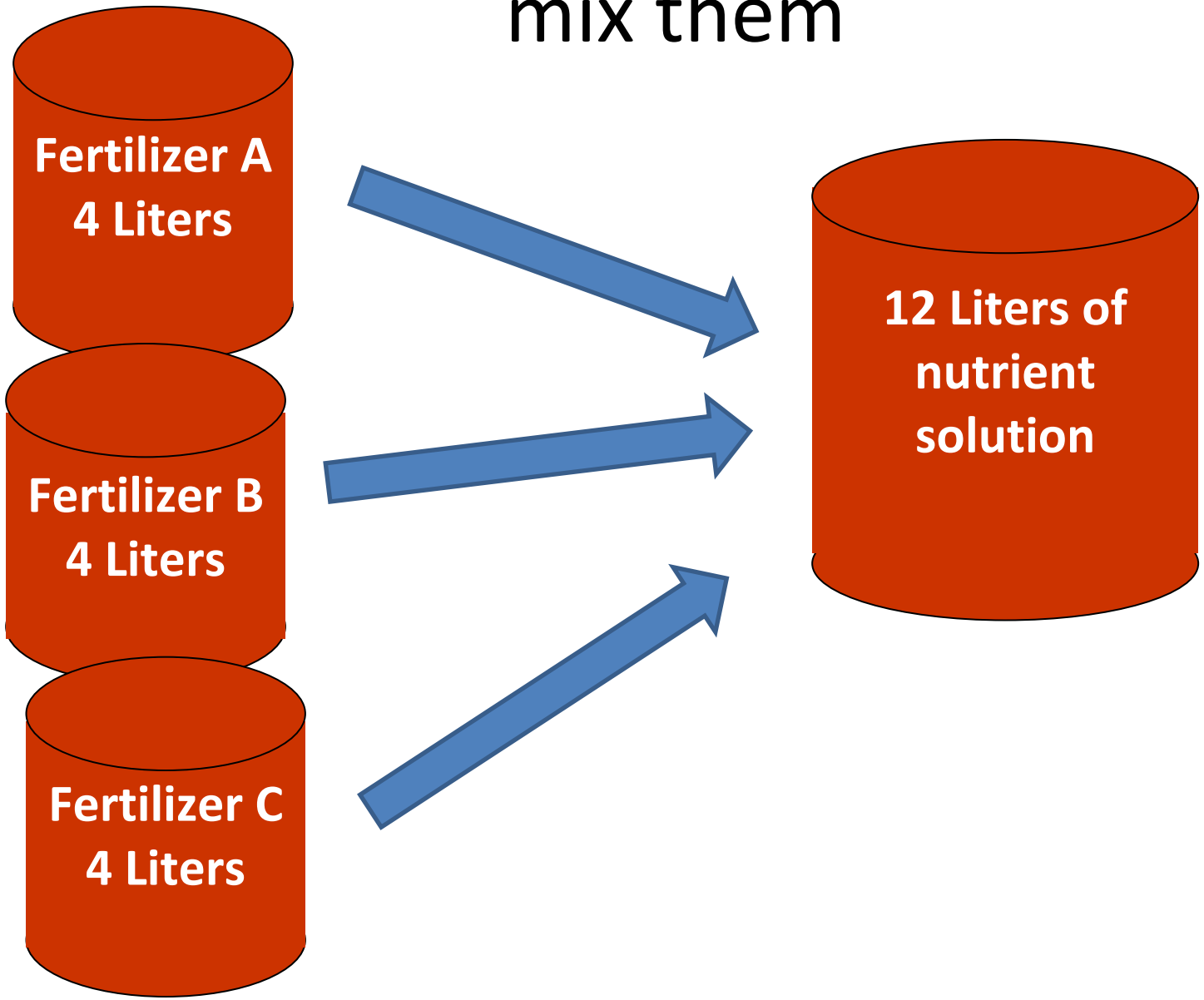
- Calcium with phosphorous
- Calcium with sulfates

Precipitated solids
(Calcium sulfate)

Option 1: Separate incompatible salts in different concentrated tanks



Dissolve fertilizers separately then mix them



Taking care of tomato plants

- Seed sowing to transplant, approx. 4 weeks
- First flower cluster: 4-6 weeks after transplant
- Place sticky traps near vents, doors, and at the canopy level of the crops to monitor for insects
- **Measure** pH and EC every 2 days and adjust pH when necessary **For inert media*
- **Monitor** for insect damage, diseases, yellowing or abnormal growth
- **Prune** lower leaves and adjust plant on the trellis: every 2 weeks
- Tomatoes need **pollination**! 4 times per week
- Replace nutrient solutions when needed

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Pollinating tomatoes

- There are no pollinators inside a greenhouse or a vertical farms
- Pollination is needed to increase yield and fruit size
- You can order a box of bumblebees that will last for 12 weeks, and it is good for 1,400 to 5,700 sq ft (too many can damage flowers) **For greenhouses and hoop houses, unknown for indoor farms*
- Tap the trellis wire twice a day at least 4 days a week
- Use electric air blowers every day for 5 seconds


THIS IS NOT JUST A BUMBLEBEE
THIS IS NATUPOL
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THIS IS NATUPOL

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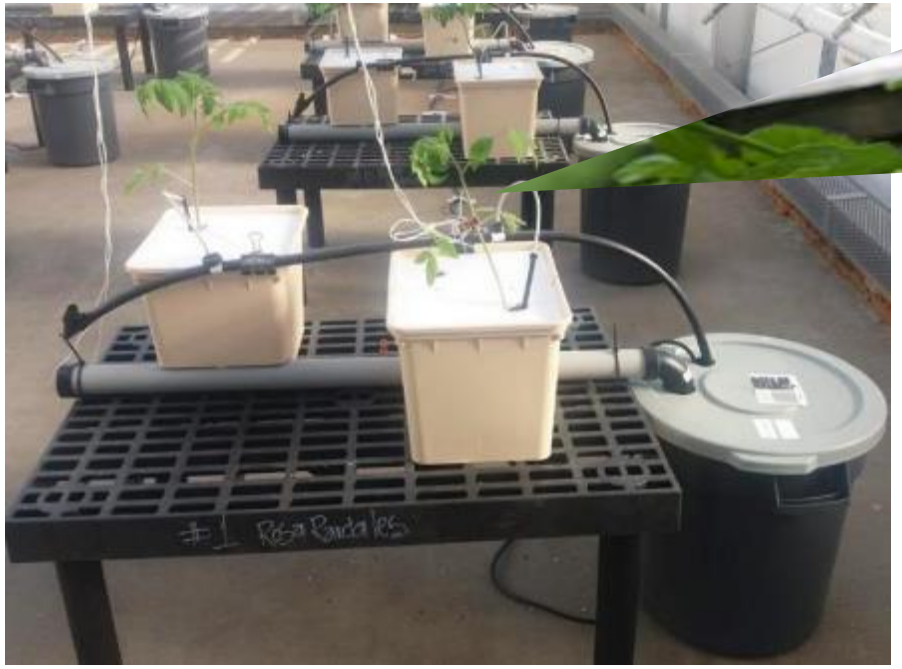
Trellis system

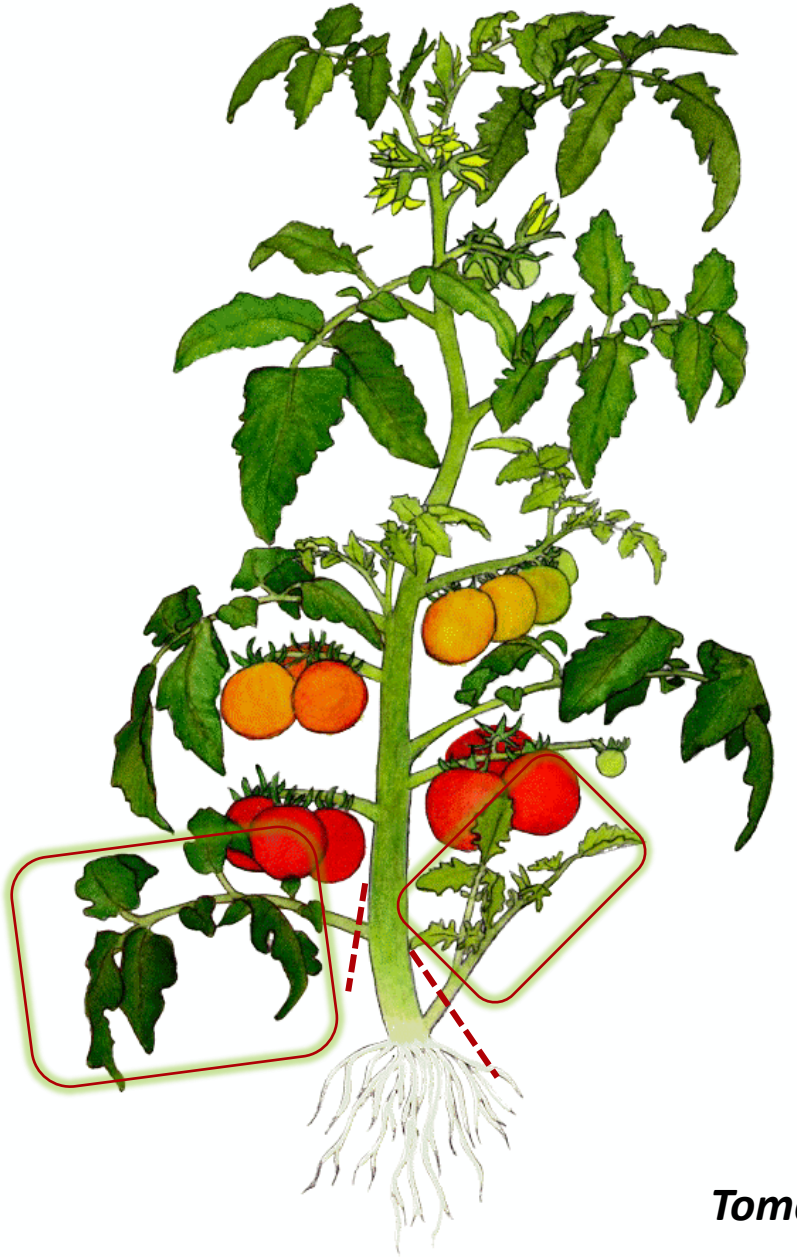


Highwire system: 20 pounds per foot
Training: central leader

Pruning

Improved air circulation = Less disease pressure

Makes it easy to train the tomato plants



Remove any suckers

Remove lower leaves no longer needed for production: all leaves under the first fruit cluster

Tomato plant illustration by K. Tomlinson
Available at
https://cals.arizona.edu/hydroponictomatoes/pruning.htm

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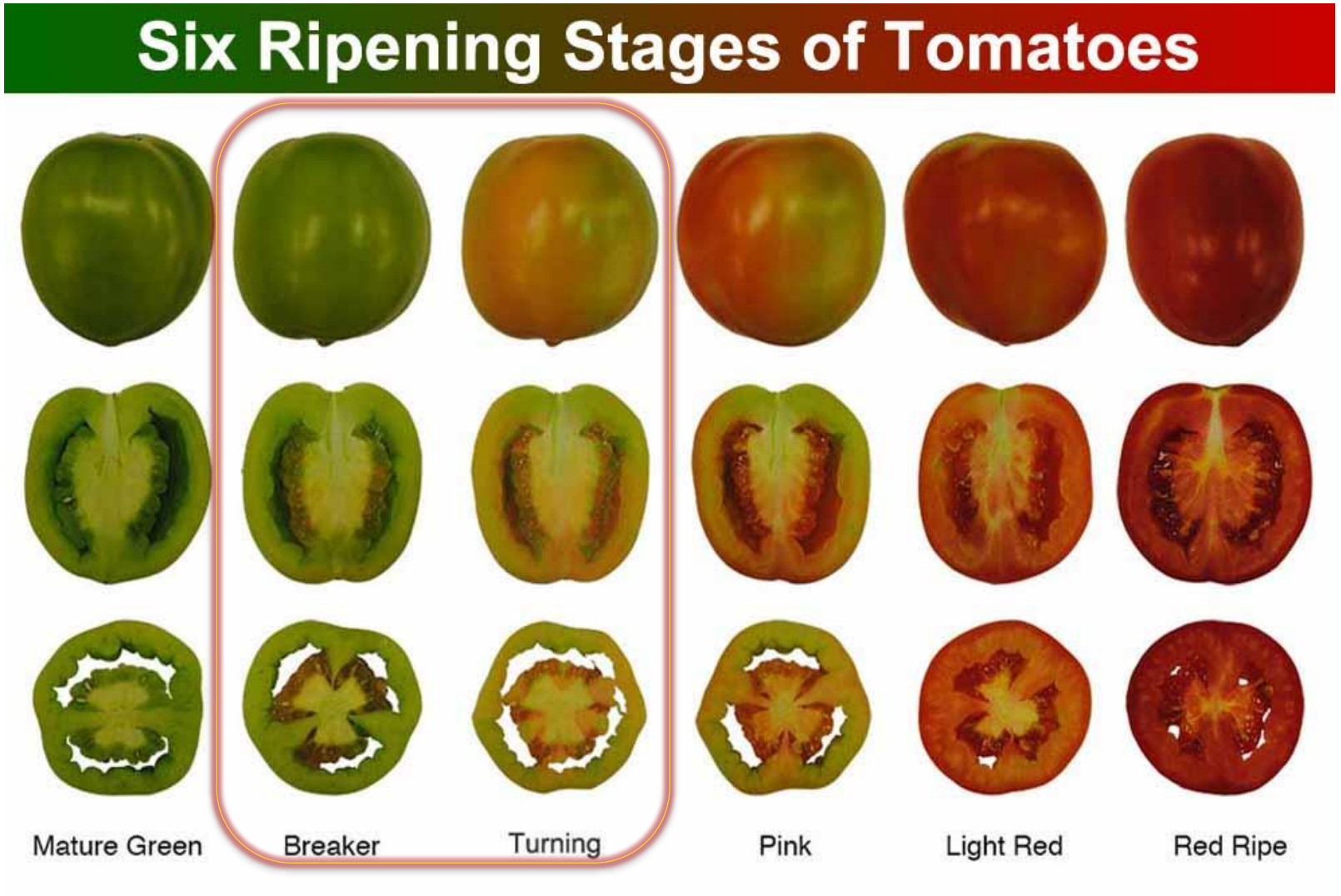
Tomato harvest and post harvest



Source: Organic Farming and Gardening School

Tomato harvest and post harvest

- **Harvest: Lift and pull**
  - Green: long distance shipping and needs ethylene treatment to induce ripening
  - Ripe: shorter shelf life but with better taste
- **Post-harvest:**
  - Mature green: 58-60°F lasts 21-28 days
  - Pink: 48-50°F lasts 7-14 days
  - Red: 55 °F lasts 2-4 days
  - Relative humidity: 85-95%

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Common problems

1. Environmental problems
2. Plant diseases
3. Insect pests

Abiotic vs biotic

- Biotic problems: caused by a living organism (develops over time with sporadic occurrence)
- Abiotic problems: caused by the environment (instant and general occurrence)

Not a disease!

Blossom end rot

Caused by environmental conditions that limit the absorption of calcium. Even when calcium levels are adequate in the soil!

Calcium enters the roots with water!

Factors that will limit water uptake include days with high relative humidity and inconsistent watering.

Not a disease!

How to prevent blossom end rot?

- If growing indoors make sure you have a fan exchanging air around the plants to avoid stagnant humid air.
- Open the greenhouse/high tunnel vents to allow for air exchange and lower air humidity. (1 exchange/hour)
- Remember to keep the soil moist but not saturated when watering.
- Avoid prolonged periods of drought, specially when the fruits are growing.

Not a disease!

Caused by high temperatures, inconsistent watering, and intense sunlight exposure can affect fruit development and ripening.

Solutions

- Increase airflow to lower air temperature
- Use of shade cloth rated between 20 to 50% shade.
- Shade cloth will lower air temperature between 6 to 9 °F and should be installed when temperatures are going to be over 85°F.

Common problems

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2. Plant diseases
3. Insect pests

Plant pathogen dispersal

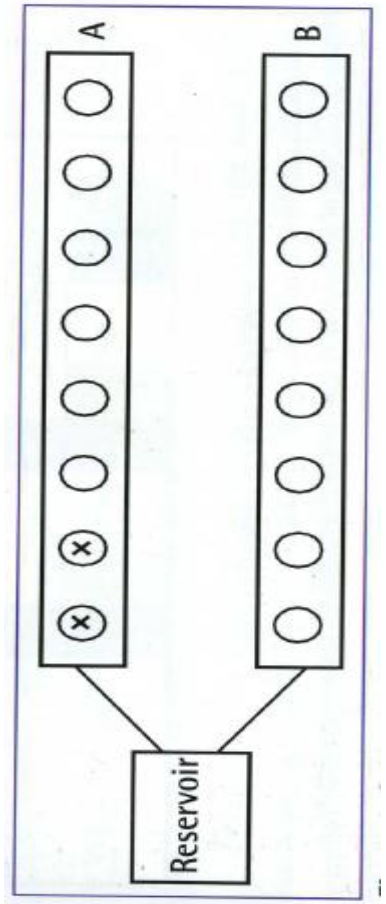


Fig. 4. Mortality of pepper plants on the inoculated and noninoculated side of a two-sided ebb-and-flow cultural system in the (A) absence or (B) presence of a surfactant in the recirculating nutrient solution. X = the inoculated plants that served as the source of secondary inoculum.

Stanghellini et al., 2000

Diseases

- **Damping-off and root rots**: Use high quality water or consider treating the water. Use a *Trichoderma* drench as preventive biocontrol.
- **Mildews and white mold (Sclerotinia)**: Increase air circulation especially horizontal flow. Increase plant spacing. If growing indoors, consider a dehumidifier.
- **Botrytis (gray mold)**: likes cool and wet weather. Avoid watering at night. Remove affected plants and improve air circulation.
- **Leggy plants with yellow foliage**: Lack of light, overcrowding or lack of nutrients.

Preventing diseases: Environment

- **Keep plants in their comfort zones: pH, dissolved oxygen, temperature, and proper fertility**
- **Use good quality water**
  - Municipal water ($$) or well water ($)
- **Consider water treatment if you don't have access to good quality water**
  - Solid separation → Filtration → Sanitation
- **Use certified disease-free seeds and resistant varieties**
- **Ensure good air circulation: spacing and pruning**

Preventing diseases: Equipment

- **Keep the outside perimeter free of weeds**
- **Avoid reusing potting mixes**
- **Start with clean surfaces**
  - Wash off debris, scrub with soap, and rinse
  - Sanitize (follow label instructions): quaternary ammonium (Green-Shield®, Physan 20®, and Triathlon®), hydrogen dioxide (ZeroTol®, Oxidate®) and chlorine dioxide (Selectrocide™)
- **Keep floors clean**

Preventing diseases: Control

- **When in doubt contact your Extension Specialist**
- **Use chemical pesticides as last resort**
  - Read the pesticide label: This is a binding contract
  - Do you have a pesticide applicator license?
  - Is it labeled for the crop?
  - Is it labeled for use indoors or in greenhouse?
  - Is it labeled to control the intended pest?
  - Do you have the required protective and application equipment?
  - Rotate chemicals (FRAC code) to prevent resistance
- **Consider biocontrol options: http://greenhouseipm.org/ipm-basics/ http://anbp.org**

Common problems

1. Environmental problems
2. Plant diseases
3. Insect pests

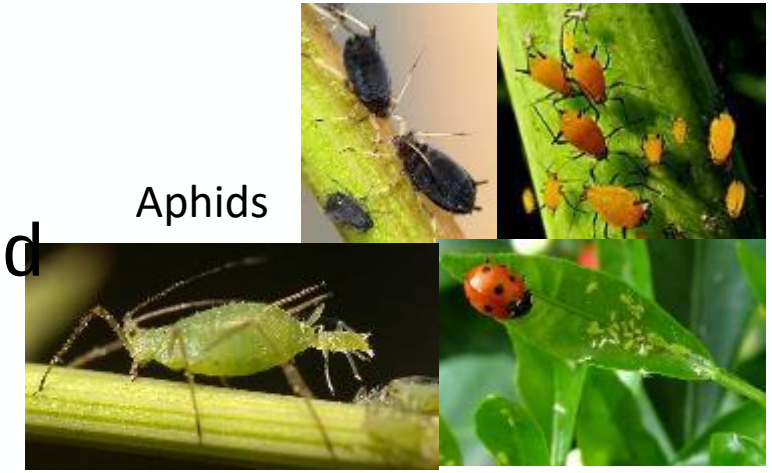
Monitoring for pests

- **Use sticky traps to scout for insects**
  - At plant height
  - Yellow: fungus gnats, aphids, thrips, whiteflies, and leaf miners
  - Blue: whiteflies
  - One trap per 1,000 square feet
  - Additional traps as needed near vents and doors
  - Always inspect the plants
- **Identify the pests and the damage they cause (some transmit plant diseases)**
  - Identity will help you identify proper control

Sticky traps

Common insect pests

- Thrips, aphids, whiteflies, fungus gnat, and shoreflies
- **Cultural control**: resistant varieties, prevention measures, insecticidal soaps, horticultural oils, neem oil.
- **Chemical control**: Read the label! The label is the law! Rotate products (IRAC code)
- **Biological control**: predatory insects and beneficial fungi



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https://extension.tennessee.edu/publications/documents/pb1594.pdf

Chemical control

- **You need training to get a private pesticide applicator training**
- **Always rotate pesticides with different FRAC or IRAC codes to prevent resistance development**
- **Read the label: this is a legal binding contract**
  - Intended pest, for the specific crop, and adequate personal protective equipment
  - Ensures the responsible use of chemical pesticides
- **Re-entry and pre-harvest intervals**