Module 5
Tomato Morphology and Plant Steering

2026 Greenhouse Hydroponic Tomato Workshop with Dr. Triston Hooks

Outline

1. Tomato Production
2. Tomato Morphology
3. Plant Growth and Support
4. Plant Steering

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Dr. Merle Jensen

Tomato Morphology and Plant Steering

Tomato Production

- Tomatoes were one of the first crops to be established in CEA, globally
- Tomatoes have been a focus at the UA-CEAC for 25+ years!
- Greenhouse hydroponic tomatoes serve as a model for other CEA crops

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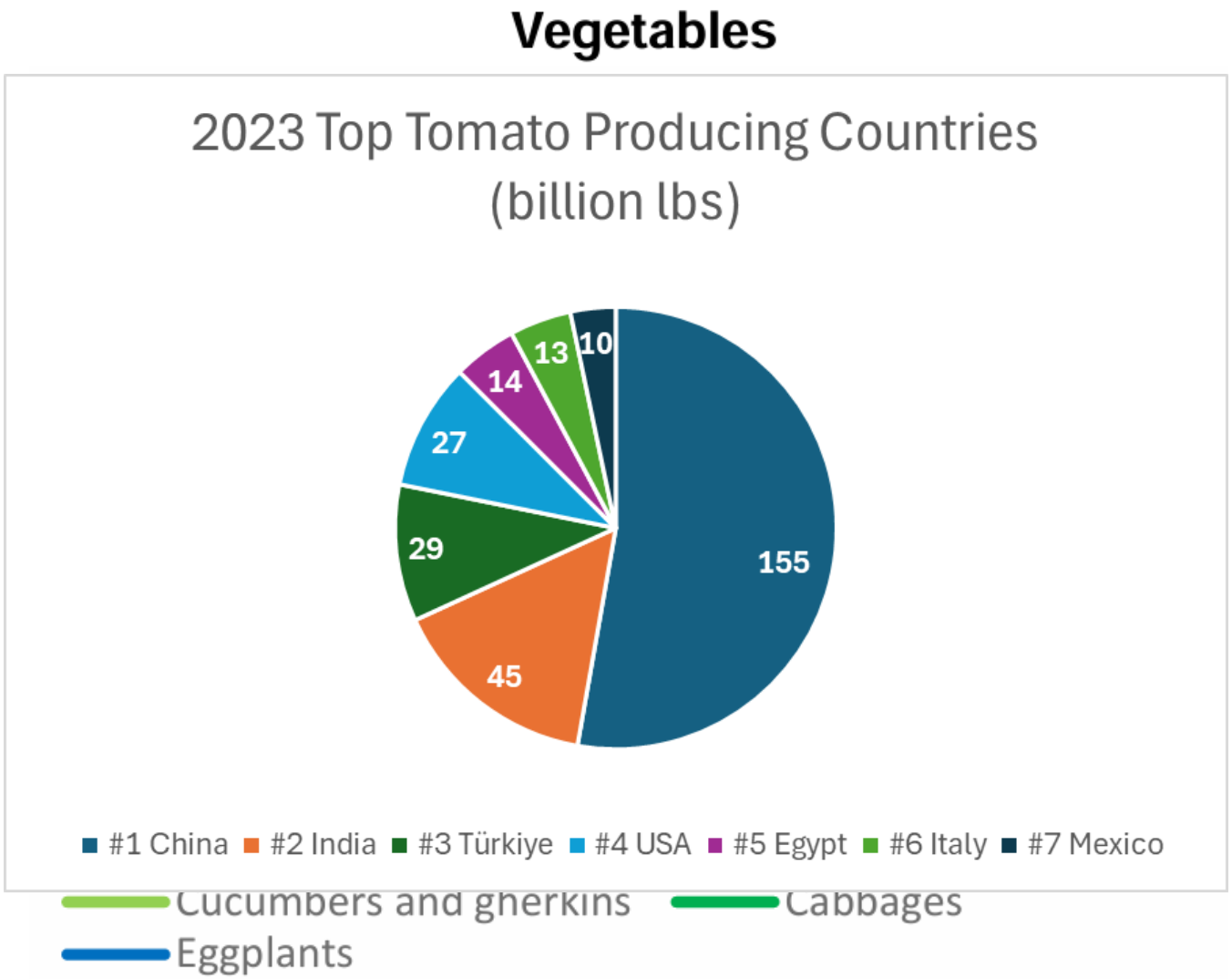
Tomato Morphology and Plant Steering

Tomato Production

- Tomatoes are the #1 vegetable produced and consumed each year throughout the world!
- Global tomato production is increasing up to 440 billion lbs/yr!
- The US is ranked #4, producing 27 billion lbs/yr of tomatoes



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DiMare Farms, UA-CEAC

Tomato Morphology and Plant Steering

Tomato Production

- Majority of tomatoes in the U.S. are grown in California and Florida during Summer in the open field
- Poor soil, unfavorable weather, and pests/diseases/viruses are challenges…

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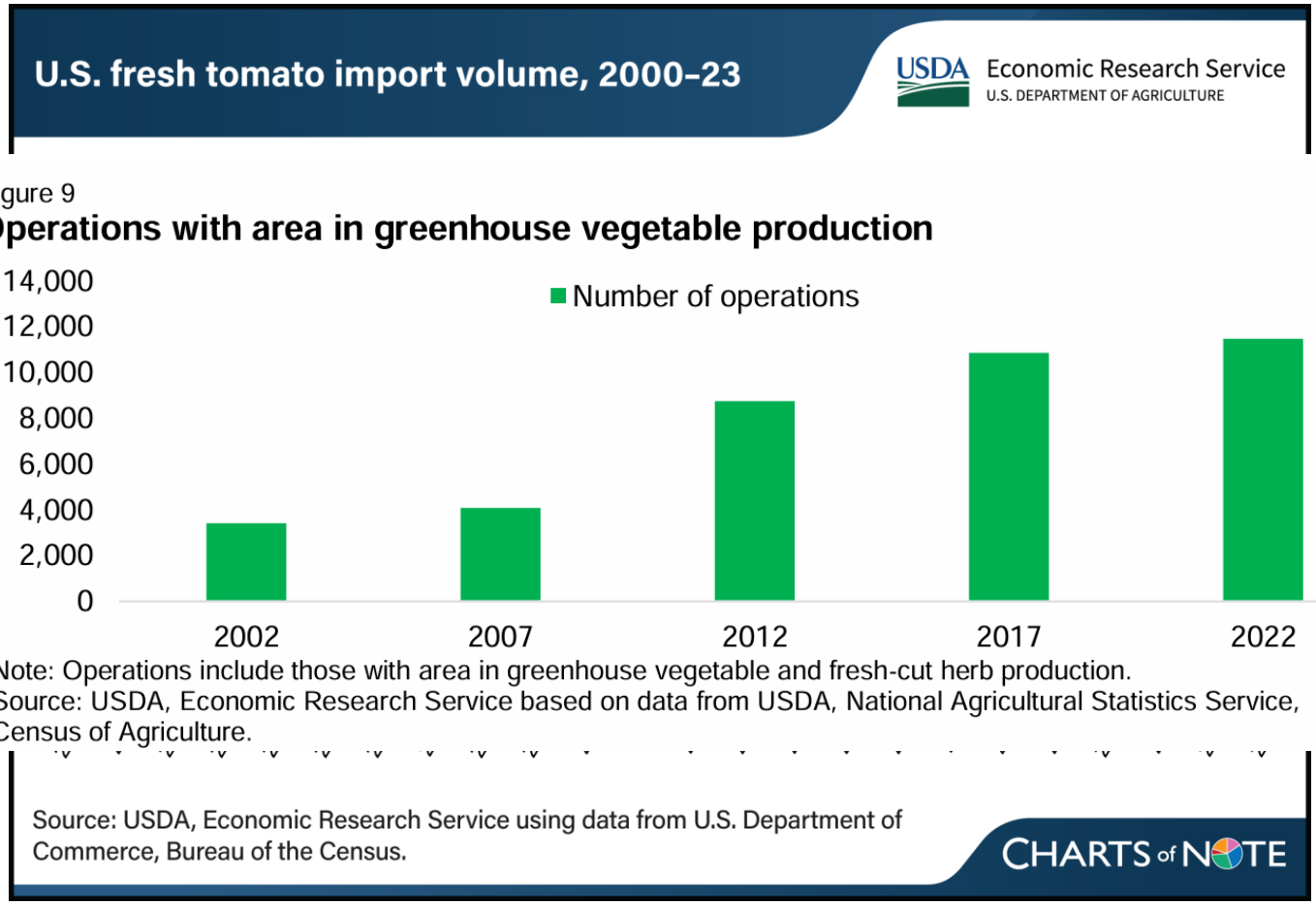
Tomato Morphology and Plant Steering

Tomato Production

- Nevertheless, the US has been relatively slow to adopt CEA technology
- Most greenhouse hydroponic tomatoes in US grocery stores are imported from Can or Mex
- However, there is growing demand for local and sustainably grown produce



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Tomato Morphology and Plant Steering

Tomato Production

- Eurofresh/Nature Sweet ~500 acres (AZ, TX, MEX)
- Wholesum Family Farms ~100 acres (AZ, MEX)
- Village Farms ~150 acres (TX, CAN, BC)
- Mucci Farms ~60 acres (OH, CAN)

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UA-CEAC, Eurofresh

Tomato Morphology and Plant Steering

Tomato Production

- Determinate tomato plants have a determined growing point, are harvested annually, and have a smaller growing habit, like a bush

- Indeterminate tomato plants have an indetermined growing point, are harvested continually, and have a larger growing habit, like a vine

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Tomato Morphology and Plant Steering

Tomato Production

- Greenhouse hydroponic tomatoes are grown for ~9 months, depending on the method
- Although indeterminate tomato plants can grow indefinitely, at some point vigor declines and pest/pathogen pressure increases

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Tomato Morphology and Plant Steering

Tomato Production

- Indeterminate tomato vines can grow up to 50 ft long!
- But the longer the plant grows the greater demand and strain for water, nutrients, and photosynthates
- Yield can decline after ~9 months of continuous production

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Tomato Morphology and Plant Steering

Tomato Production

- Both the age of the plant and the growing environment can contribute to pest/pathogen pressure
- Moisture, decomposing plant debris, and aging plants can create a perfect storm for a plant disease or insect pest to become established

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Tomato Morphology and Plant Steering

Tomato Production

- There is increased risk and diminishing return to grow the plants for more than ~9 mo
- It is more productive and cost-effective to remove the plants, clean the greenhouse, and transplant new tomato plants
- This is done every school year at the UA-CEAC!

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Eurofresh

Tomato Morphology and Plant Steering

Tomato Production

- Alternatively, intercropping is the practice of establishing the next crop cycle alongside the current cycle to avoid a production gap

- However, this method is not recommended due to the potential carryover of pests and pathogens to the next crop cycle

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Mucci Farms

Tomato Morphology and Plant Steering

Tomato Production

- A more viable production method is to segregate growing areas into staggard production times

- This enables one sector to be producing while another is being cleaned

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Month	Week	Day	Tomato Timeline	Nutrient Solution	*Greenhouse
Jan	0	0	Sow / Germination	Tap water	Remove old substrate
Jan	1	7	Emergence		Clean and Sanitize
Jan	2	14	Seedling Establishment		
Jan	3	21	Boost	Recipe 1/2x	Prepare System and Substrate
Jan	4	28	Transplant	Recipe 1/2x	
Feb	5 – 8	35 - 56	Vegetative Establishment	Recipe 1	
Mar	9 – 12	63 – 84	Generative Growth	Recipe 2	
Apr	13	91	First Harvest!	Recipe 3	
Apr – Nov	13 – 47	91 – 329	Continuous Production	Recipe 3	
Dec	48 – 51	336 – 357	Top Plants Finish Harvesting	Recipe 2	
Dec	52	364	Remove Plants	Turn off fertigation	

Hooks

Tomato Morphology and Plant Steering

Tomato Production

- Example of a one-year greenhouse hydroponic tomato production timeline
- Takes 3 months until the first harvest and plants continue to produce for a total 9 months
- Plan for the next crop cycle while greenhouse cleaning and preparation happens*

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Tomato Morphology and Plant Steering

Tomato Production

- To end a tomato production cycle, top the plants by pruning off the heads 2- 4 weeks before termination
- This halts vegetative growth and directs the plants to finish developing fruit
- Continue pruning suckers!

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Tomato Morphology and Plant Steering

Tomato Production

- After the final harvest, fertigation can be turned off and plants can be removed
- Substrate needs to be tossed, composted, or cleaned
- Plant debris needs to be swept and removed from the gutters and floor

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Tomato Morphology and Plant Steering

Tomato Production

- Gutters, irrigation lines, and floors can be cleaned with a pressure washer
- Soapy water, 10% bleach, 1% Zerotol, or hypochlorous acid can be used to sanitize
- The goal is to eliminate any potential plant pathogens and pests

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Tomato Morphology and Plant Steering

Tomato Production

- A clean and sterile growing space is needed for the next crop cycle
- Anticipate 1 – 4 weeks to clean and prepare a growing area
- This can depend on the size of the growing area, available labor, and if repairs are needed

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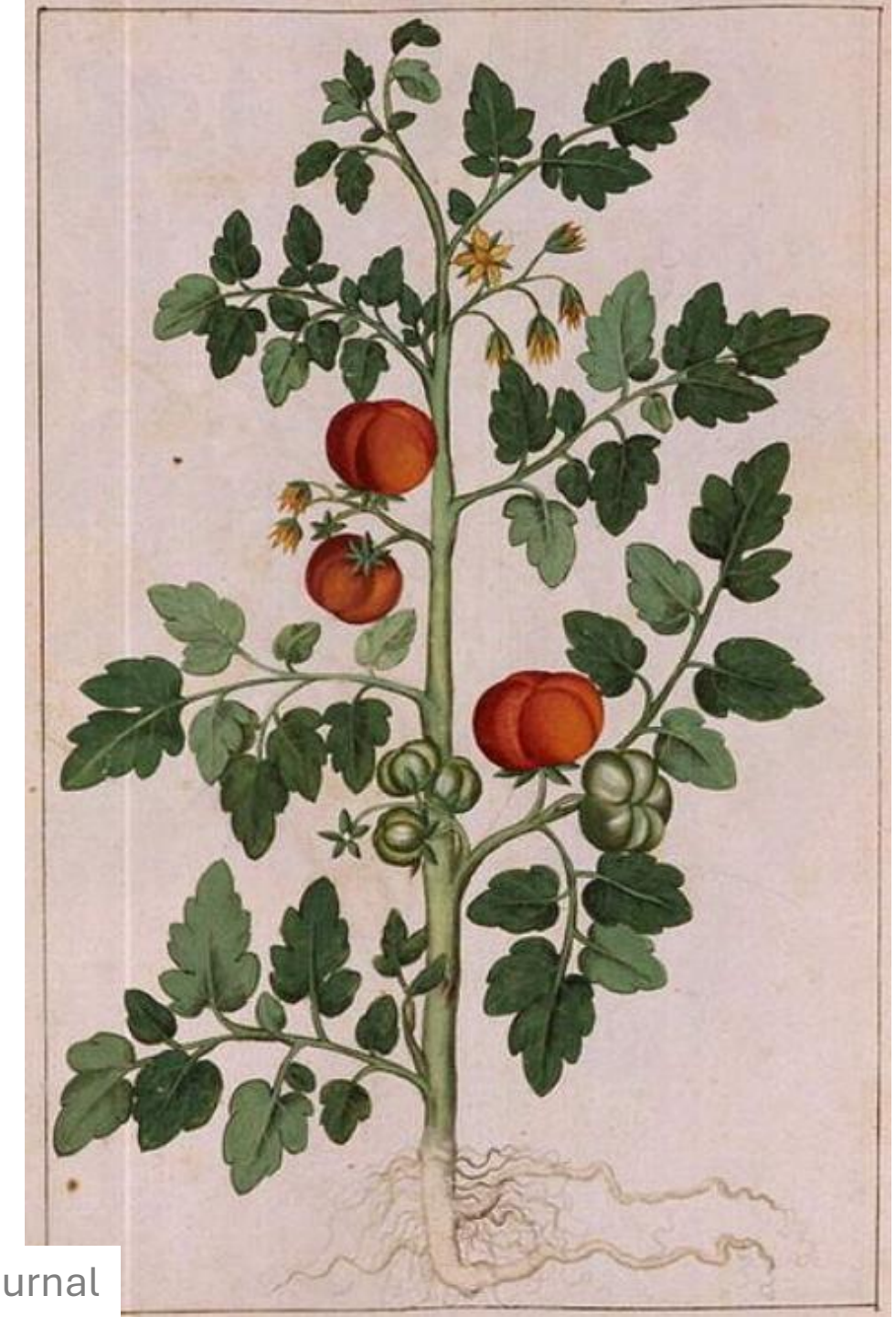

Botanical Journal

Tomato Morphology and Plant Steering

Tomato Morphology

- Tomato (*Solanum lycopersicum*) is an herbaceous perennial fruiting plant
- Family Solanaceae (Nightshades)
- Lycopene is an antioxidant that gives tomatoes their vibrant red color

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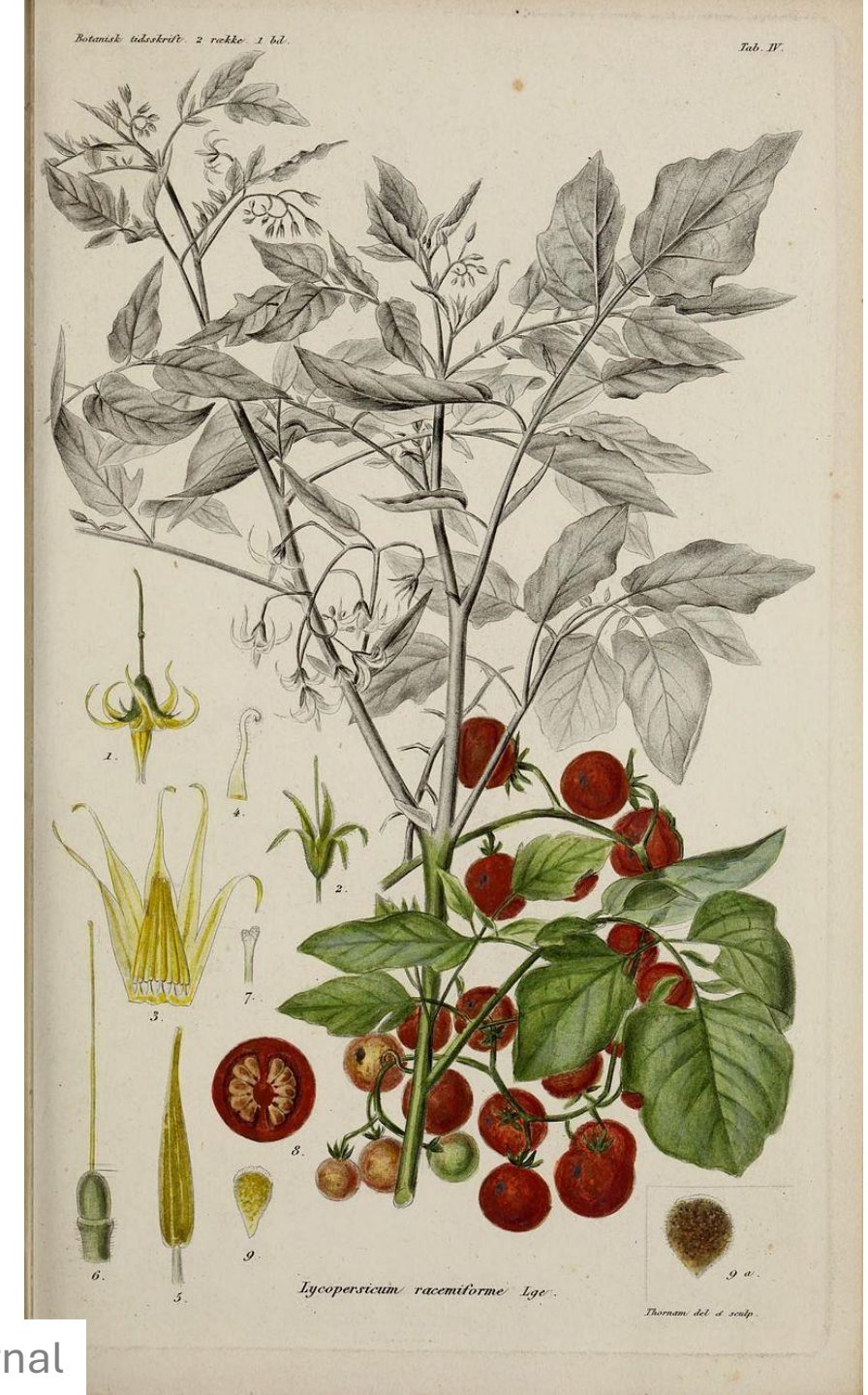

Botanical Journal

Tomato Morphology and Plant Steering

Tomato Morphology

- The wild species of tomato (*Solanum pimpinellifolium*) is a tropical plant native to central and south America
- Grows very small tomatoes aka “pimps”
- Source of genetic diversity that can be used to breed new tomato cultivars

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Tomato Morphology and Plant Steering

Tomato Morphology

- Greenhouse tomato production utilizes the growing habit of indeterminate tomato plants to grow year-round tomatoes
- Understanding tomato morphology is key to successfully growing!

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Tomato Morphology and Plant Steering

Tomato Morphology

- An indeterminate tomato plant has a single main stem that grows like a vine
- The stem supports the growth of leaves, trusses, and suckers in an organized pattern

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Tomato Morphology and Plant Steering

Tomato Morphology

- At the top of the main stem is the head of the plant, which is the primary growing point (apical meristem)
- Be careful, the head has young and delicate plant tissue that needs to be protected!

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Tomato Morphology and Plant Steering

Tomato Morphology

- A close-up view of the apical meristem showing unfolded plant tissue
- Notice the glandular trichomes found all over the tomato plant that secrete a sticky and aromatic sap

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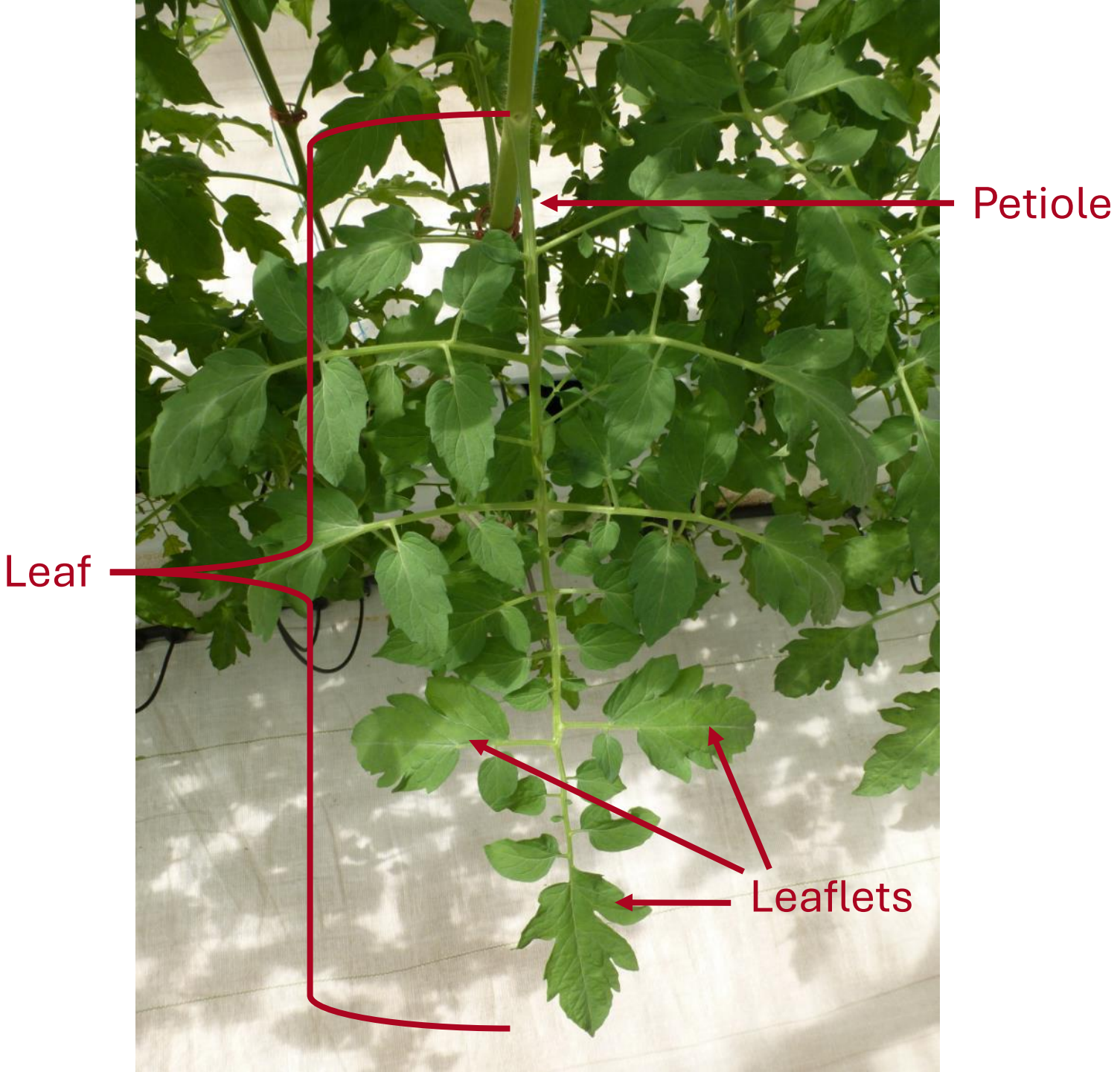

Tomato Morphology and Plant Steering

Tomato Morphology

- Tomato leaves are compound (a single leaf composed of many leaflets)
- The stem of the leaf is called the petiole
- A greenhouse hydroponic indeterminate tomato plant grows three leaves per week

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Tomato Morphology and Plant Steering

Tomato Morphology

- Tomato trusses are branches that bear multiple flowers and fruit in a cascade pattern (oldest to youngest)
- A greenhouse hydroponic indeterminate tomato plant grows one truss per week

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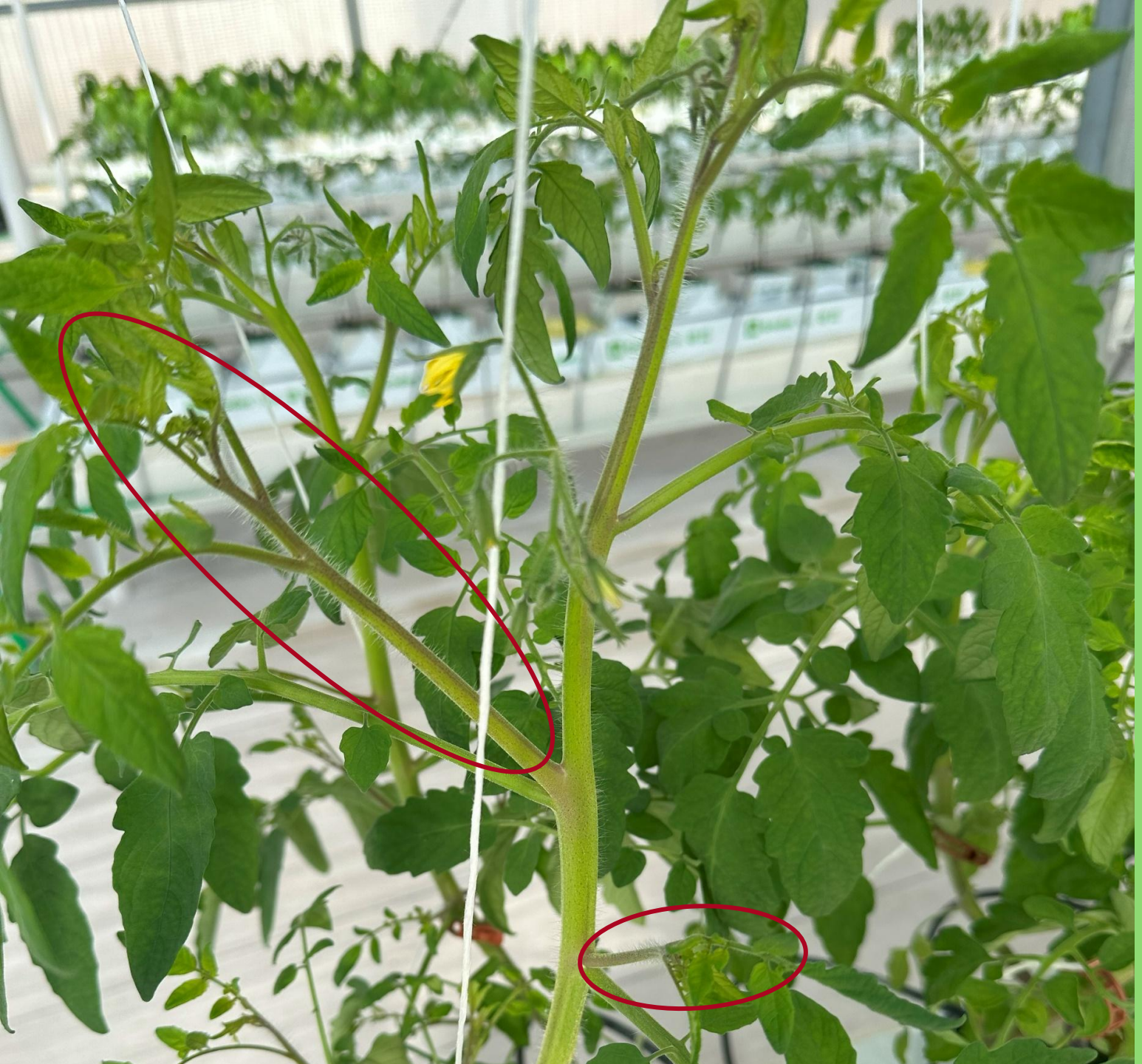

Tomato Morphology and Plant Steering

Tomato Morphology

- Tomato suckers are lateral shoots that grow from the main stem
- Suckers are redundant growing points that can compete with the apical meristem
- Suckers “steal” water and nutrients from leaves, flowers, and fruit

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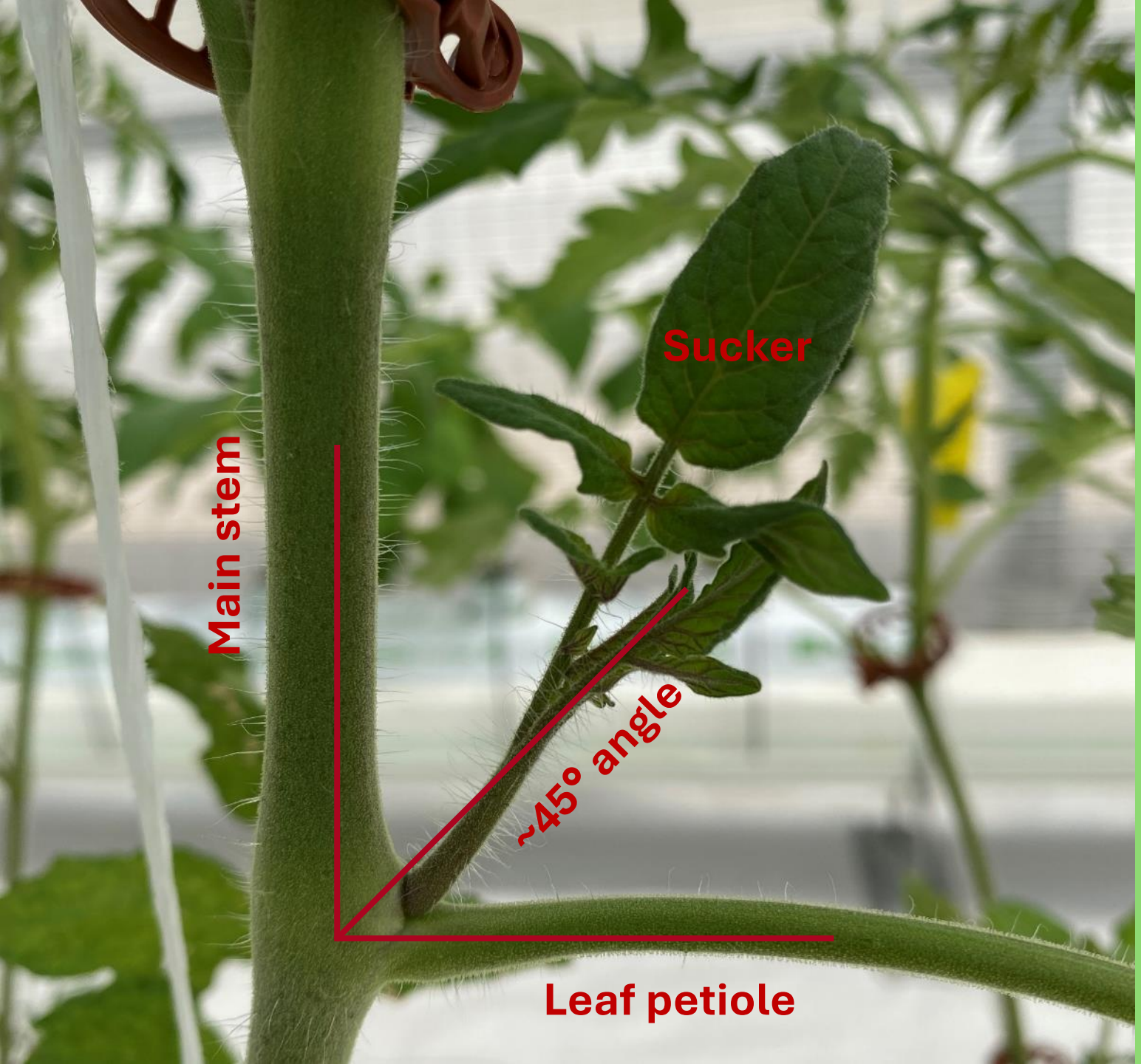

Tomato Morphology and Plant Steering

Tomato Morphology

- Suckers grow from nodes along the main stem, directly above leaves
- Suckers can be identified by their ~45 degree angle between the main stem and leaf petiole

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Tomato Morphology and Plant Steering

Tomato Morphology

- Pinch/remove suckers from indeterminate tomato plants to maintain a single growing point at the head

- Suckers can be snapped off at the abscission zone, a natural breaking point

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Tomato Morphology and Plant Steering

Tomato Morphology

- Clean breaks heal quickly and prevent infection from plant pathogens
- Avoid fractured breaks which heal slowly and are open to infection from plant pathogens
- If the sucker can't easily be removed by hand, then carefully use pruners

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Tomato Morphology and Plant Steering

Tomato Morphology

- Suckers are sneaky…
- Although suckers primarily grow from lateral nodes, they can also grow from the leaf petiole and truss!
- Carefully remove suckers wherever you find them on the tomato plant, don’t delay!

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Tomato Morphology and Plant Steering

Tomato Morphology

- Searching and removing suckers is a weekly task for greenhouse hydroponic tomatoes!

- This is a component of plant steering, which is the job of a grower – to help plants grow their best!

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Tomato Morphology and Plant Steering

Tomato Growth and Support

- Greenhouse hydroponic indeterminate tomato plants grow an average of 12 inches (~1ft) each week*
- Vine twine is used to support the plants as they grow
- The twine is spooled on tomahooks which hang from above on steel cables

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Tomato Morphology and Plant Steering

Tomato Growth and Support

- C-clips are attached to the vine twine to support the main stem as it continuously grows
- The teeth of the C-clip should grab the twine for a secure attachment

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Tomato Morphology and Plant Steering

Tomato Growth and Support

- C-clips should be attached directly underneath the petiole of a leaf for maximum support
- Avoid attaching C-clips to trusses or above leaf petioles
- C-clips need to be able to support the weight of a 20lb tomato plant!

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Tomato Morphology and Plant Steering

Tomato Growth and Support

- Rule of thumb: Do not attach C-clips or prune suckers near the head (top ~6 inches) of the plant to protect it!

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Tomato Morphology and Plant Steering

Tomato Growth and Support

- Attach one C-clip per plant using the following guides:
  - Each week, or…
  - For every 12 inches of main stem growth, or…
  - For every three leaves, or…
  - For every truss*

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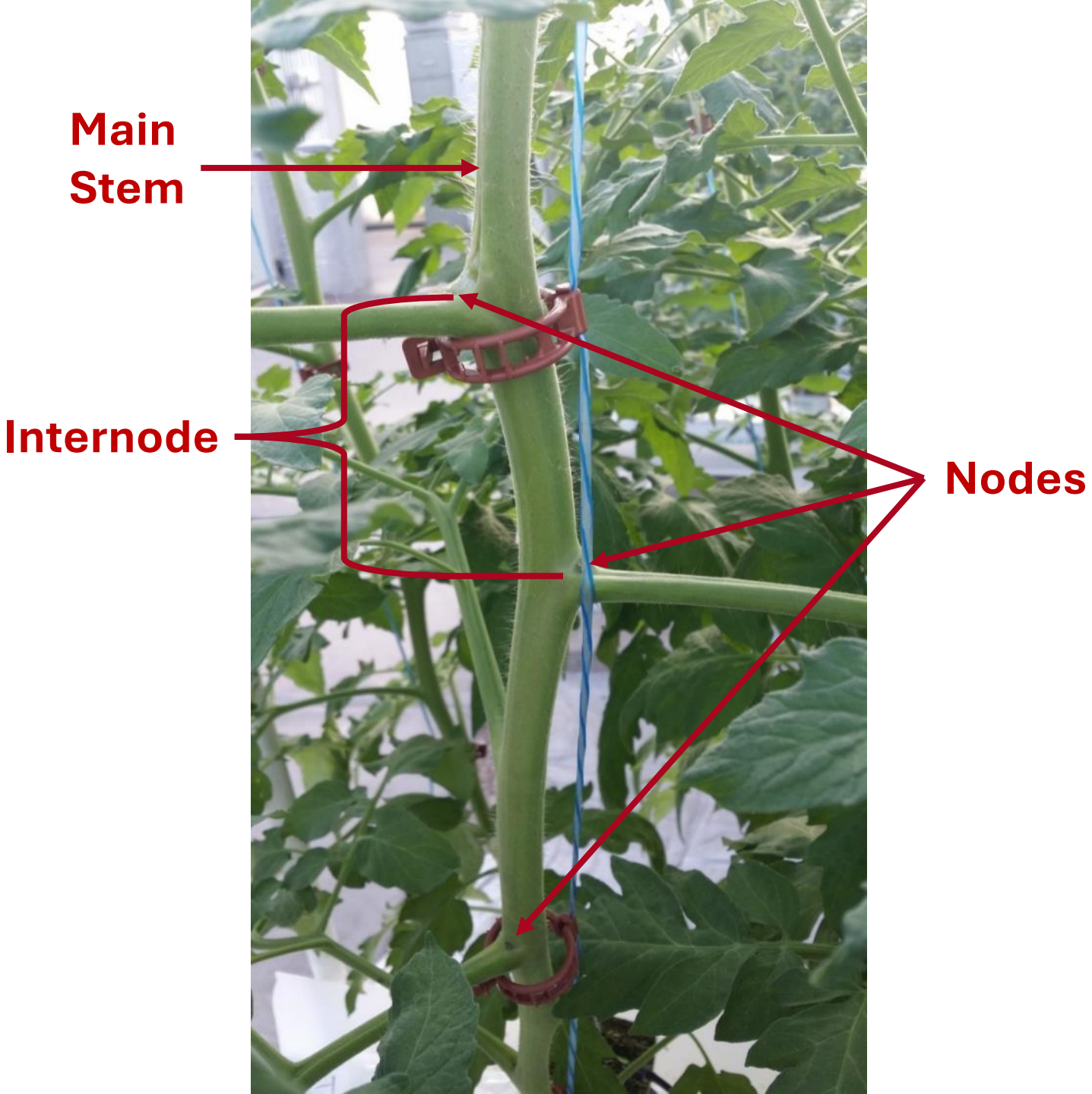

Tomato Morphology and Plant Steering

Tomato Growth and Support

- A hydroponic indeterminate tomato should have a clear main stem with clean nodes
- The distance between two nodes is the internode
- The stem and internode can be used to measure the vigor of a tomato plant

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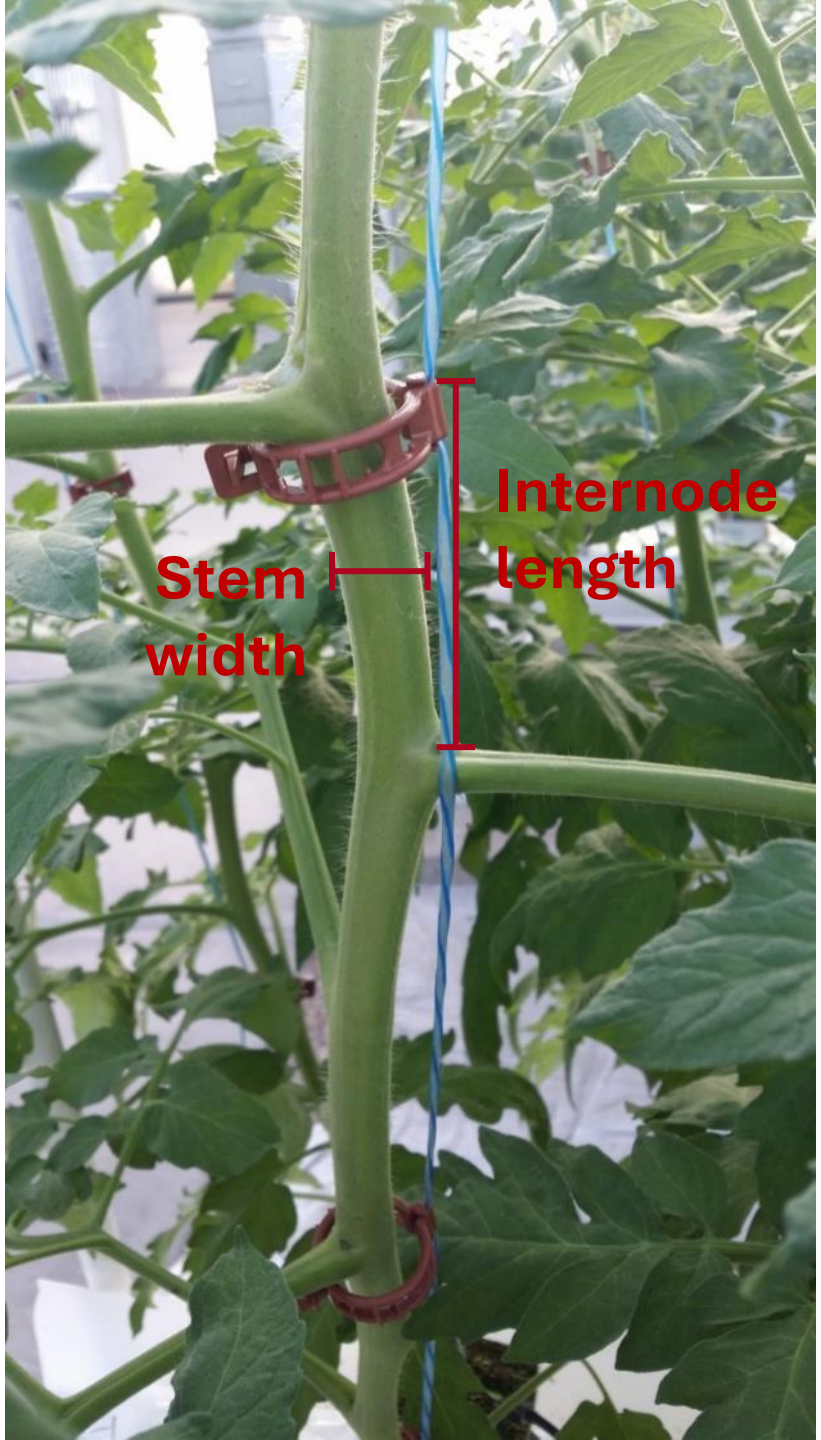

Tomato Morphology and Plant Steering

Tomato Growth and Support

- Tomato growth guide:

Growth	Stem thickness	Internode length
Slow or vegetative (thick stem and short internode)	>1 inch	<2 inch
Good/Balanced (strong stem and normal internode)	~1 inch	~3 inch
Poor or generative (thin stem and long internode)	<1 inch	>4 inch

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Tomato Morphology and Plant Steering

Tomato Growth and Support

- Tomato overall growth can be measured and recorded on a weekly basis
- Align the head of the tomato plant with the vine twine and mark the twine
- Each week, measure the distance between each consecutive mark on the twine

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Tomato Morphology and Plant Steering

Tomato Growth and Support

- *How are the long vines of indeterminate tomato plants managed during ~9 months of production?*

- A technique called lowering and leaning is used to wrap the tomato stems and maintain a consistent growing canopy!

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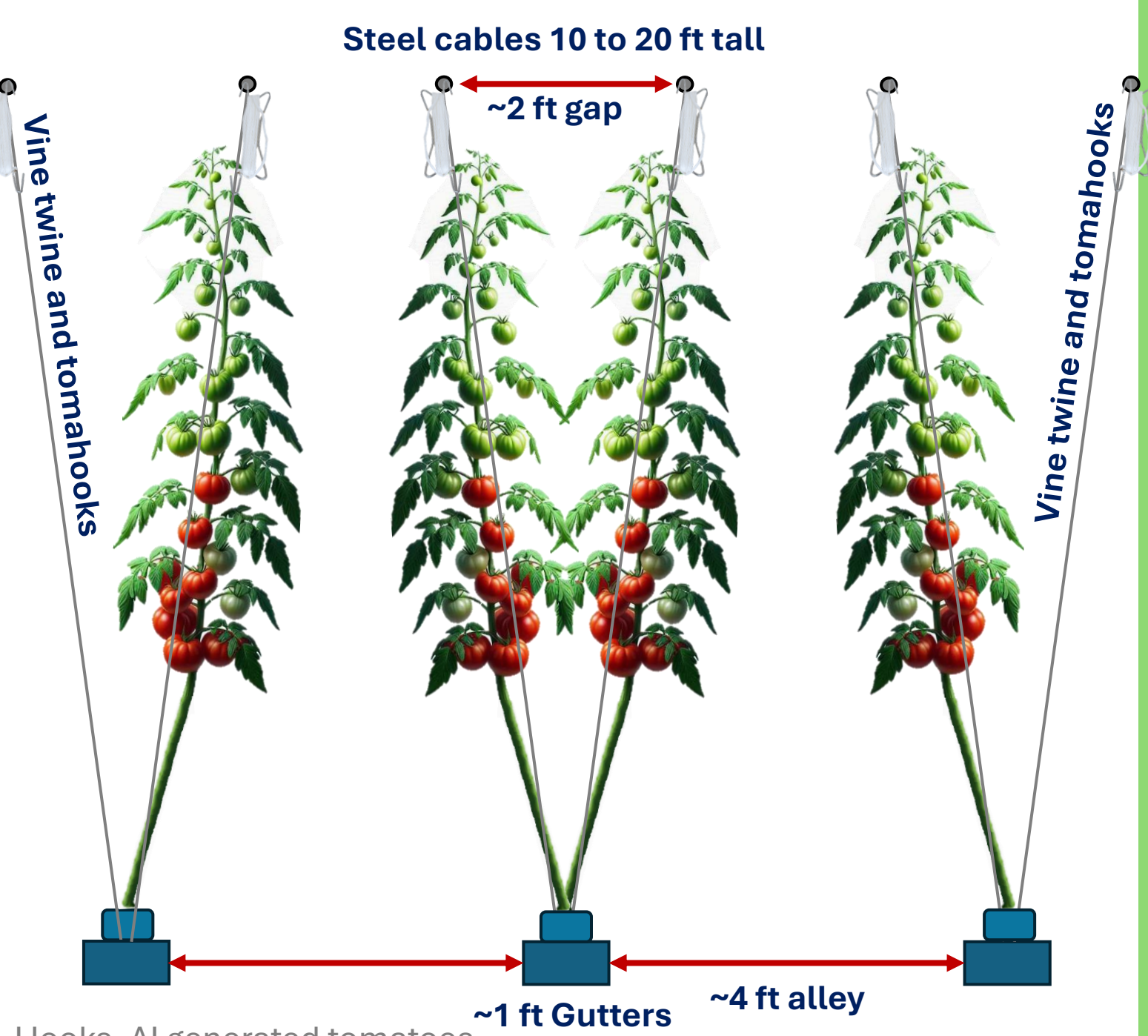

Hooks, AI generated tomatoes

Tomato Morphology and Plant Steering

Tomato Growth and Support

- For each gutter, there is a pair of steel cables positioned above to create a "V" shaped growing area to maximize plant density
- Plants are trained to each side of the "V" in an alternating pattern using the vine twine

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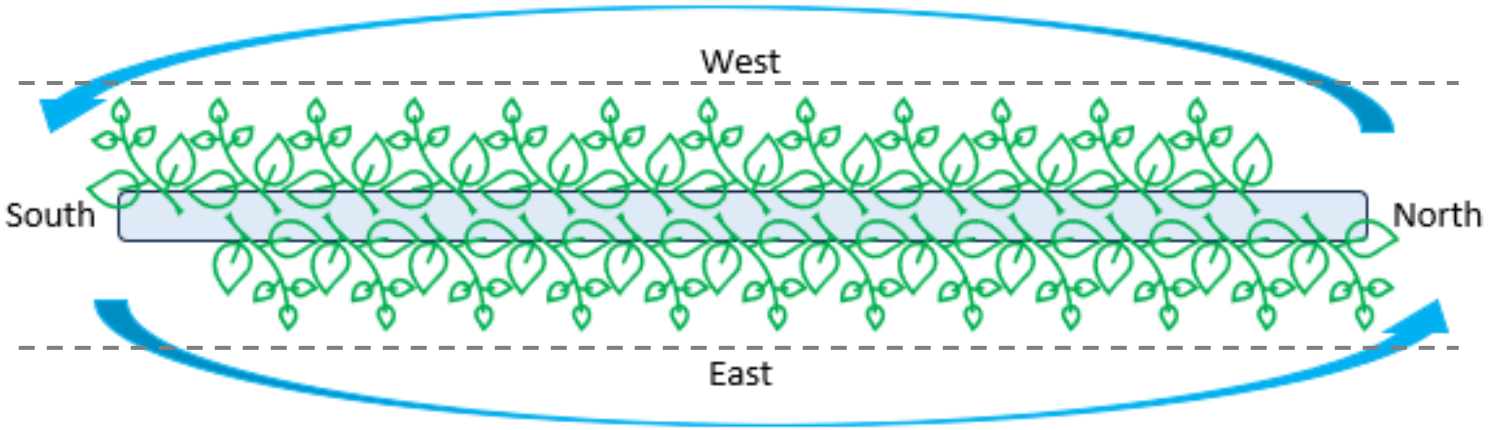
Tomato Morphology and Plant Steering

Tomato Growth and Support

- Notice the alternating plant pattern of plants from this top-down view
- To achieve this, lean each plant by moving the tomahook to the right (always to the right when facing the plants)

Lean the plants in the same direction to create a pattern and maintain plant density!



At the end of the row, the plants are turned to the other side to continue the pattern!

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Tomato Morphology and Plant Steering

Tomato Growth and Support

- At the end of each tomato row, posts are positioned to enable the tomato stems to turn/wrap around and continue growing

- To turn a tomato plant at the end of the row, move the tomahook to the steel cable on the other side of the row/gutter

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Tomato Morphology and Plant Steering

Tomato Growth and Support

- *What about “lowering”?*
- Extra twine is released from the tomahooks, and the plants are “lowered and leaned” to maintain growing space for the upper canopy
- Rule of thumb: For each plant, lower ~1 ft and lean ~1 ft each week to allow new growth!

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Tomato Morphology and Plant Steering

Tomato Growth and Support

- Be careful not to “lean” the plants too much!
- The stems should be relaxed without tension and have a gentle curve

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Tomato Morphology and Plant Steering

Tomato Growth and Support

- *What happens to the lower canopy of the plant?*
- Stems should be supported and kept off the ground
- Lower leaves are pruned and C-clips can be removed
- Tomatoes are harvested!

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Tomato Morphology and Plant Steering

Summary

- We covered tomato production, morphology, growth and support!
- Each week, hydroponic tomato plants grow:
  - 3 leaves
  - 1 truss
  - ~12 inches of main stem
  - And lots of suckers!

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Southern Exposure Seeds

Tomato Morphology and Plant Steering

Plant Steering

- Plants have instincts to… survive!
- Plants can focus on vegetative growth with redundant growing points (leaves, suckers, and roots)
- This increases short-term survivability from physical damage and stress

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Home and Garden

Tomato Morphology and Plant Steering

Plant Steering

- Plants can also focus on generative growth (flowers, fruit, and seed) to complete their lifecycle
- This increases long-term survivability
- Plant growth types are driven by physical and environmental cues!

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Tomato Morphology and Plant Steering

Plant Steering

- Plants also have extensive genomes with desirable traits (e.g. color, taste, texture, shape, size, smell, etc.)
- Desirable traits are typically not expressed under stress/survival conditions
- To grow their best, plants need help from a grower – you!

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Tomato Morphology and Plant Steering

Plant Steering

- As a grower, your job is simple: prevent plant survival instincts!
- Nurture the plant with what it needs (water, nutrients, environment, support)
- This is called plant steering, and the goal is to enable plants to grow their best!

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A balanced growth state means the plant has equal vegetative and generative growth types and is prevented from swinging too far in either direction

Tomato Morphology and Plant Steering

Plant Steering

- Plant steering guides the plant between vegetative and generative growth types
- For greenhouse hydroponic tomatoes, a grower steers the plants first towards vegetative growth, then generative
- But the majority of production time requires balanced growth

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Tomato Morphology and Plant Steering

Overview of Greenhouse Hydroponic Tomato Steering		
Duration	Growth Type	Goal
First ~2 months	Vegetative	Seedlings and transplants establishing roots and leaves
~1 month	Generative	Established plants transitioning to produce flowers and fruit
~8 months	Balanced	Fully grown plants focused on sustained growth and production

Hooks

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Tissue	Vegetative	Balanced	Generative
Leaves	Dark green, thick, twisting down	Green and open, perpendicular to the main stem	Light green, thin, upwards growth
Stem	Thicker	Normal (finger width)	Thinner
Internode	Shorter	Normal (~3 in)	Longer
Suckers	Prolific	Normal	Few
Truss	Thin, long, upright	Strong and cascading	Extensive and branching
Flowers	Too few, pale yellow	Normal per tomato type	Too many, dark yellow
Fruit	Too few, small, poor quality	Normal amount, large, best quality	Too many, various quality*

Adapted from Dr. Merle Jensen

Tomato Morphology and Plant Steering

Plant Steering

- *How do you recognize vegetative and generative growth?*
- Get to know your plants, they will tell you!
- Plant morphology is key but tomato type and variety can also influence growth types

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Tomato Morphology and Plant Steering

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- Vegetative growth example:

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Tomato Morphology and Plant Steering

- Generative growth example:

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Tomato Morphology and Plant Steering

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Adapted from Dr. Merle Jensen

- Balanced growth example:

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Tomato Morphology and Plant Steering

Plant Steering

- *How do you steer a tomato plant?*

    1. Physical/Mechanical steering

    2. Environmental steering

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Tomato Morphology and Plant Steering

Plant Steering

- Physical/Mechanical plant steering involves interacting with the plant through pruning and support
- Pruning involves removing excess plant tissue, regularly
- Support involves providing the plant with the space and structure to continue growing

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Tomato Morphology and Plant Steering

Plant Steering

- Leaf pruning involves removing the oldest leaves from the lower canopy
- The plant will naturally senesce older leaves
- Pruning leaves in the lower canopy helps the plant stay vigorous, allows airflow, and can reduce pest/pathogens!

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Tomato Morphology and Plant Steering

Plant Steering

- *How do you prune leaves?*
- Make clean cuts close to the main stem (don't leave stubs!)
- Remove ~3 leaves per week to keep up with expected growth
- In general, avoid over-pruning (>30% of leaf tissue) which can shock the plant

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Tomato Morphology and Plant Steering

Plant Steering

- Without proper pruning, tomato plants in the greenhouse will grow excessively vegetative, overwhelm their production space, entangle one another, and deplete their yield potential!

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Tomato Morphology and Plant Steering

Plant Steering

- Pruning leaves and suckers are critical to plant steering, and push the plant towards generative production

- Rule of thumb: prune vegetative tissue to steer the plant generative; prune generative tissue to steer the plant vegetative

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Tomato Morphology and Plant Steering

Plant Steering

- Environmental steering involves altering the environmental conditions to signal the plant towards vegetative or generative growth

- Environmental conditions include air temperature, light, CO_2, water, nutrients, EC, pH, and more…

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Tomato Morphology and Plant Steering

Plant Steering

- Remember, with CEA, environmental conditions can be optimized for plant growth
- However, optimal conditions for vegetative and generative growth are different
- A skilled grower can tailor a CEA environment to help steer tomato plants!

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Table 2: Steering plant growth for maximum yield.

Action	Reproductive Actions	Vegetative Actions
Difference in Day/Night Temperature	Greater	Smaller
24-hour Temperature	Low (<20°C)	High (>22°C)
Cooling down; Day > Night	Fast (i.e. using a Pre-night temperature strategy	Slow
VPD (Humidity)	Larger (Low R.H.)	Smaller (High R.H.)
Ventilating (Mind the outside temperature)	More	Less
CO_2	500 - 1000 ppm	300 - 400 ppm
EC in the slab	Higher (NOT more K) Tomato; 4.5+ mS Cucumber; 2.8 - 3.2 mS	Lower Tomato; 4 - 4.5 mS Cucumber; 2 - 2.5 mS
EC in the drip	Higher	Lower
Water content in the slab	Lower; 10-15% Day/Night difference	Higher and Constant; 4-6% Day/Night difference
Irrigation frequency and irrigation volume	Less frequent; Large volume per irrigation	More frequent; Small volume per irrigation
Irrigation start time	Later in the morning	Earlier in the morning
Irrigation stop time	Earlier in the afternoon	Later in the afternoon (unless root problems)
Truss pruning (tomato)	Less (leave more fruit)	More (take off more fruit)
Truss supports (tomato)	More; sooner	Less, later

Dr. Merle Jensen

Tomato Morphology and Plant Steering

Plant Steering

- In general, tomato plants respond vegetatively to ideal / comfortable conditions and generatively to mild stress conditions
- But also consider how a wild tomato plant responds to environmental and seasonal cues to survive…

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Tomato Morphology and Plant Steering

Plant Steering

- *Combining physical / mechanical steering with environmental steering equips you as a CEA grower with the skills to grow the best hydroponic tomatoes!*

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Module 5
Tomato Morphology and Plant Steering

2026 Greenhouse Hydroponic Tomato Workshop with Dr. Triston Hooks

References

- *Dr. Merle Jensen and Patricia Rorabaugh, How To Grow Greenhouse Crops*
- *Hooks, 2022-2025, UA-CEAC Teaching Greenhouse unpublished data*

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