Maximizing Vine Crop production with Proper Environmental Control

Richard McAvoy

Department of Plant Science & Landscape Architecture

University of Connecticut

richard.mcavoy@uconn.edu

860-486-2925

Environmental Control for Greenhouse Crop Production

And "Environmental Control" refers to:

- The aerial environment (what the top of the plant is exposed to – light, temperature, humidity)
- The root environment (water, nutrition)

If it vines, you can grow it in the greenhouse:

- Tomato
- Cucumber
- Pepper
- Eggplant
- Melon
- Summer squash
- Beans

Some trends in Crop Productivity, Crop Management, and Greenhouse Design & Technology:

- Steady yield increases
- Improved environmental control
- Use of LED lighting
- Grafted rootstock for vigor and disease resistance
- Efficient space utilization/automation
- Improved structures and production systems

Very tall structures with natural ventilation:

- More uniform growing conditions
- Better environmental control

Improved crop management & environmental control models

Based on a better understanding of what the crop needs

Improved lighting systems & light management strategies, especially using LEDs

Adding lighting allows you to extend the growing season and increase productivity

Emphasis on energy conservation, energy efficiency, better space utilization

- Glazing materials & coatings to retain heat and diffuse light
- Curtain systems
- Air exchange & heat recovery systems
- Co-generation (recover CO_2) & alternate energy etc.
- Improved space utilization - movable plant rows

Light Drives Plant Growth & Fruit yield

Everything starts with light

1% Increase in Light (photosynthetically active radiation or PAR) = 1% Increase in Yield

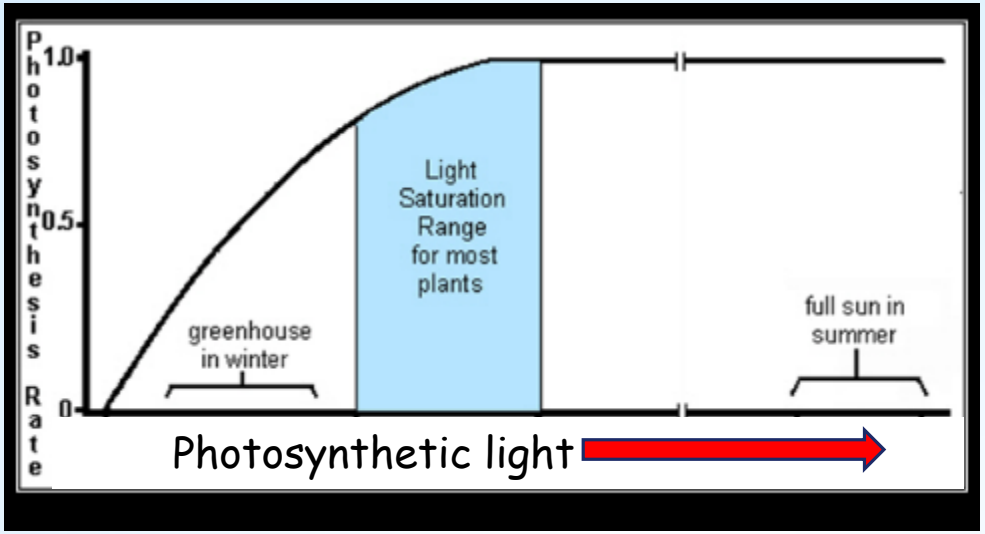
Growers have two choices:

1. Add supplemental light to boost photosynthesis & extend the production season

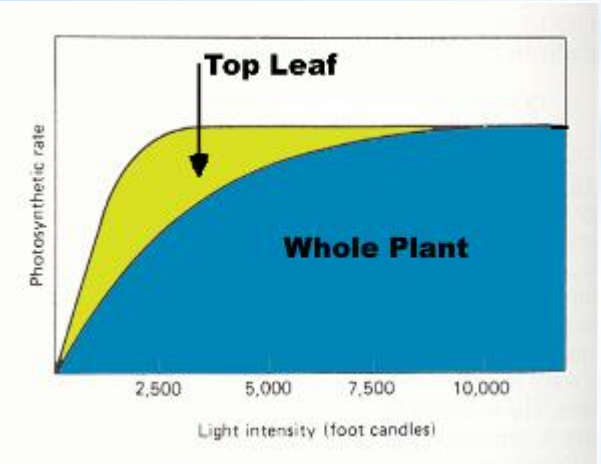
2. Grow in the seasons when natural light is adequate

In either case you also want to optimize the use of natural light by managing the crop & other environmental variables accordingly

Supplemental lighting can dramatically boost yields during light limited months of the year



Adding light to the lower leaves increases production



If you can't add light, then you have to adjust your management to optimize the light that is available

Start by maximizing natural light

Keep the glazing clean & minimize shadows

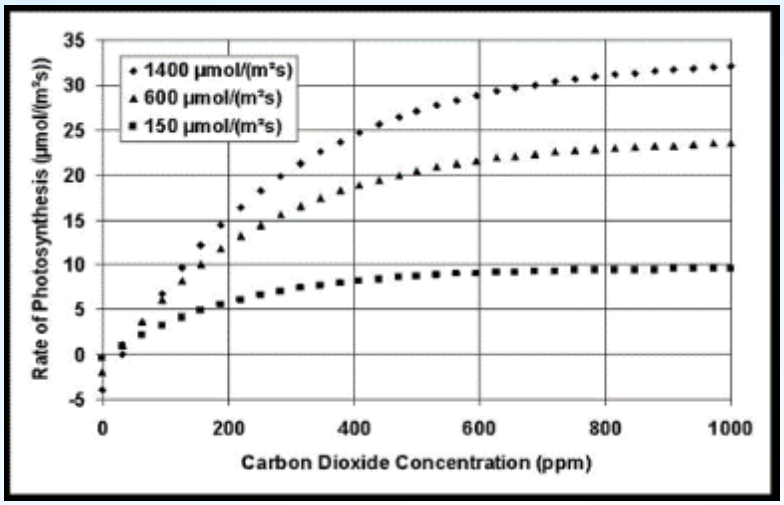
Use white reflective surfaces

Dark surfaces absorb light; White surfaces reflect light

How do you adjust crop management to maximize yield in a light limited environment?

1. Don't schedule a crop during the lowest light times of the year
2. Reduce plant density – more area per plant
3. Reduce fruit load – carry fewer fruit (to maintain vigor & size)
4. Adjust temperature – run cooler temperatures
5. Irrigation – reduce quantity
6. Fertility – higher EC
7. Maintain optimal humidity – adjust VPD to both prevent disease and optimize gas exchange

Supplemental CO_2 can also boost yields and compensate for limited light



One of the biggest concerns in the winter greenhouse is CO_2

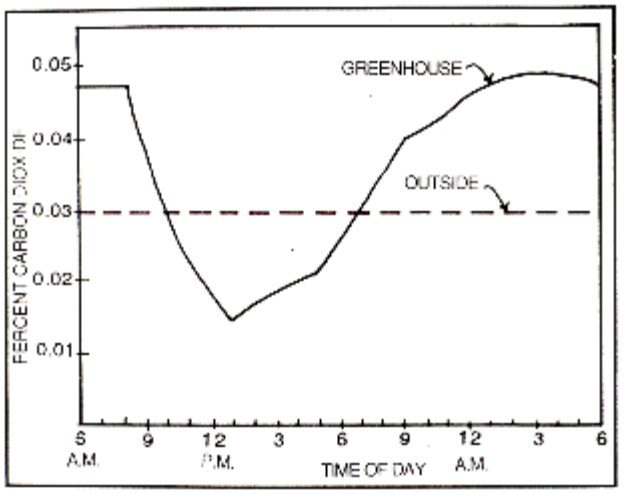


Figure 6–17. CO_2 levels in a greenhouse during a sunny day in winter compared to outside air.

Provide more space per plant in light limited months (October-March)

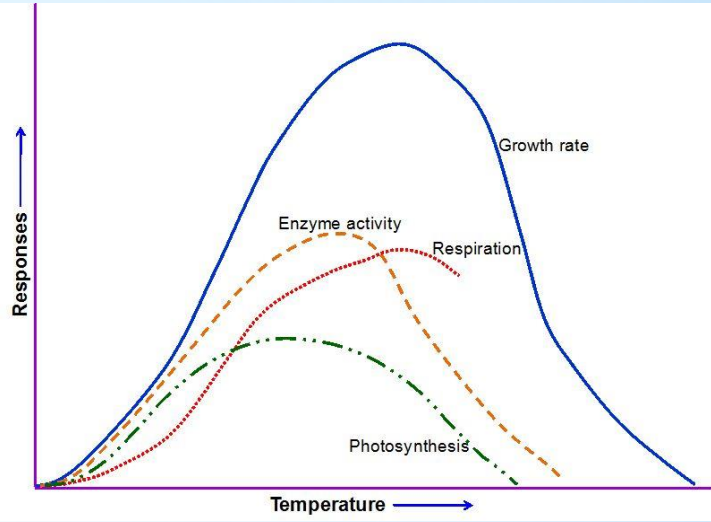
Adjust Plant Density to Optimize Fruit Quality

(sq.ft./plant)

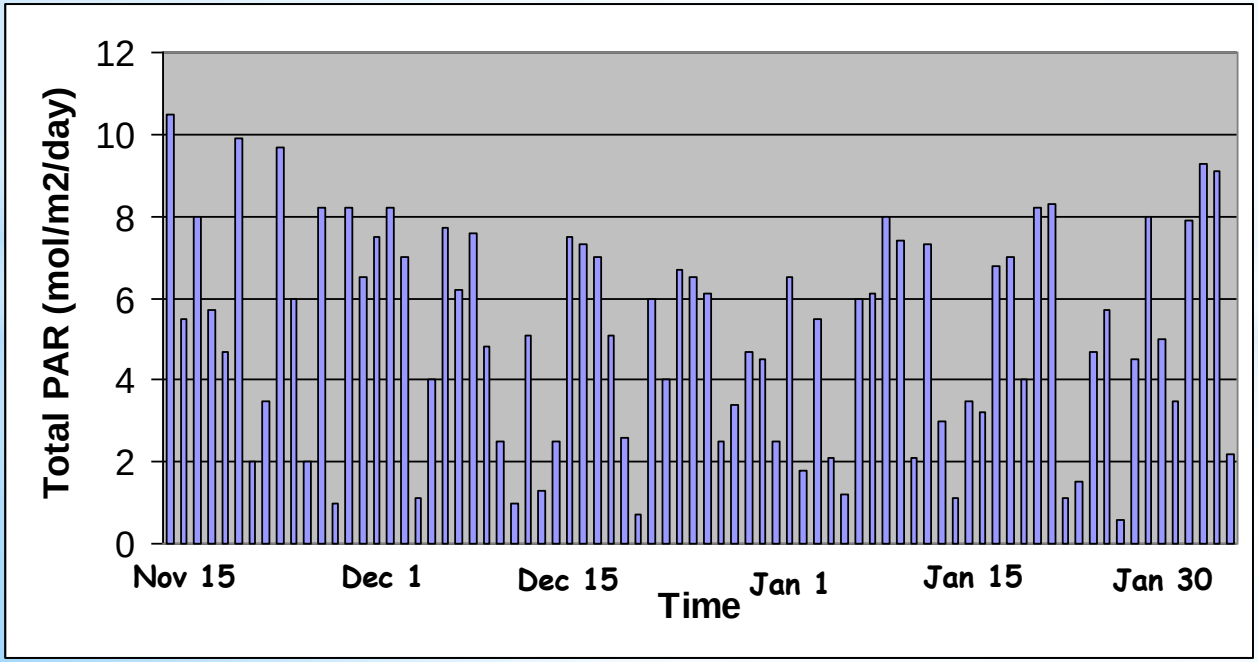
Season	Tomato	Cucumber
Light-limited	5-6	8
Light-abundant	4-5	6

Match Temperature to the Prevailing Light Environment

Temperature Controls The Rate of Plant Metabolism & Growth



Natural daily PAR available in the greenhouse



This requires both seasonal adjustments & short-term adjustments

Adjusting temperature to prevailing light conditions

- Seasonal: Cooler Average Daily Temperature (ADT) during limited light season
- Daily: Adjust night temperature to the light condition of the preceding day

Tomato for example

During light-limited seasons run cooled Average Daily Temperature (ADT):

And at night

- Run 60F following dark days
- Run 63F following bright days

During light-abundant seasons run warmer ADT:

And at night

- Run 62F following dark days
- Run 65F following bright days

Do the same thing with Cucumber & other vine crops

Cooler ADT during light-limited seasons:

And at night

- Run 62F following dark days
- Run 64F following bright days

Warmer ADT during light-abundant seasons:

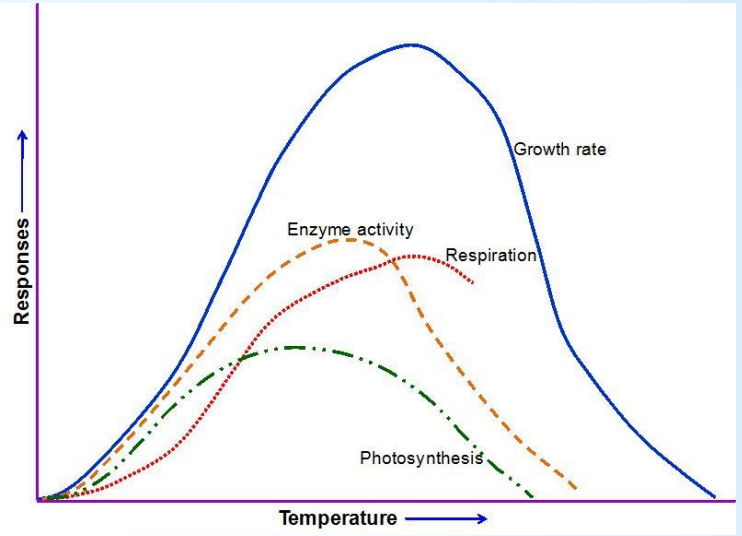
And at night

- Run 66F following dark days
- Run 70F following bright days

Heating tubes in the crop row alter temperature and metabolism in a localized parts of the plant … to boost growth & reduce disease

Excessive heat during the day will stress the plant

Evaporative cooling has the potential to reduce air temperature down to the dew point



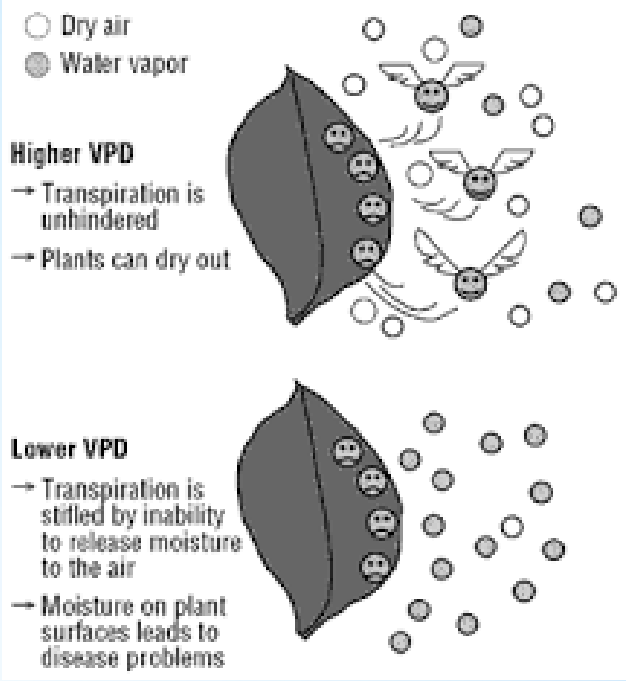
For tomato, temperatures above 85F start to increase stress, over 90F starts to have adverse effects, over 95F interferes with fruit set

Shade in the brightest part of the day can reduce temperature & water stress

Deployable shade systems are best (they give you more control) but if you can't control temperature in summer you may need to use a semipermanent shade scrim or compound

Managing humidity (Vapor Pressure Deficit or VPD) to optimize plant growth

VPD is the difference between the amount of water in the air & the maximum amount it can hold at that temperature



Effects of VPD:

- Transpiration rate
- Stomatal gas exchange & photosynthetic efficiency
- Water stress
- Nutrient movement from root to shoot
- Disease

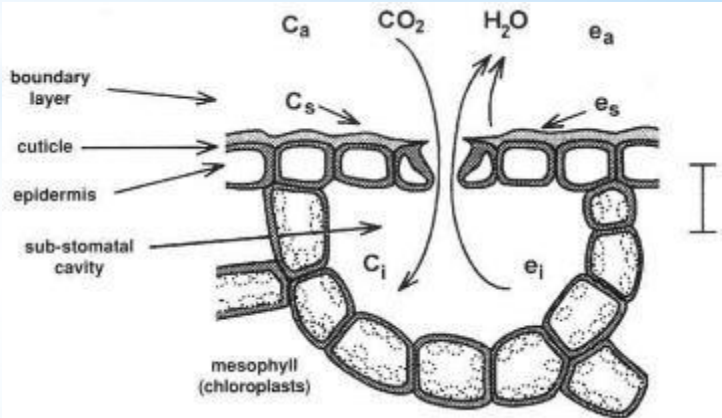
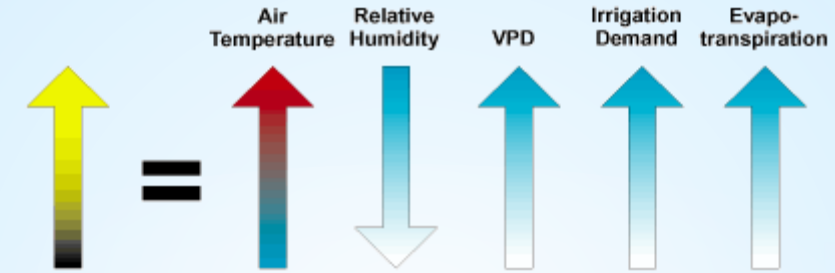


Table 1 shows the VPD in millibars at various air temperatures and relative humidity. Most cultivated plants grow well at VPDs between 8 and 10, so this is the green shaded area. Please note that the ideal VPD range varies for different types of plants and the stage of growth. The blue shaded are on the right indicates humidification is needed where the red shaded area on the left indicates dehumidification is needed.

TEMP		RELATIVE HUMIDITY													
C	F	100%	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%	45%	40%	35%
15	59	0.0	0.8	1.7	2.5	3.4	4.2	5.1	5.9	6.8	7.6	8.5	9.4	10.2	11.1
16	61	0.0	0.9	1.8	2.8	3.7	4.6	5.5	6.4	7.3	8.2	9.1	10.0	10.9	11.8
17	63	0.0	1.0	2.0	2.9	3.9	4.9	5.8	6.8	7.8	8.8	9.7	10.6	11.6	12.6
18	64	0.0	1.0	2.0	3.1	4.1	5.1	6.2	7.2	8.2	9.3	10.3	11.3	12.4	13.4
19	66	0.0	1.1	2.2	3.3	4.4	5.5	6.6	7.7	8.8	9.9	11.0	12.1	13.2	14.3
20	68	0.0	1.2	2.4	3.5	4.7	5.9	7.0	8.2	9.4	10.6	11.7	12.8	14.0	15.2
21	70	0.0	1.2	2.4	3.7	4.9	6.2	7.4	8.6	9.9	11.1	12.4	13.7	14.9	16.1
22	72	0.0	1.3	2.6	3.9	5.3	6.6	7.9	9.2	10.5	11.9	13.2	14.5	15.8	17.2
23	73	0.0	1.4	2.8	4.2	5.6	7.0	8.5	9.9	11.3	12.7	14.1	15.4	16.8	18.2
24	75	0.0	1.5	3.0	4.5	5.9	7.4	8.9	10.4	11.9	13.4	14.9	16.4	17.9	19.4
25	77	0.0	1.6	3.2	4.8	6.4	8.0	9.5	11.1	12.7	14.3	15.9	17.4	19.0	20.5
26	79	0.0	1.7	3.4	5.1	6.7	8.4	10.1	11.8	13.4	15.1	16.8	18.4	20.1	21.8
27	81	0.0	1.8	3.5	5.3	7.1	8.9	10.7	12.4	14.2	16.0	17.8	19.6	21.3	23.1
28	82	0.0	1.9	3.8	5.7	7.6	9.5	11.4	13.3	15.1	17.0	18.9	20.7	22.6	24.5
29	84	0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.1	24.1	26.1
30	86	0.0	2.1	4.2	6.4	8.5	10.6	12.7	14.8	17.0	19.1	21.2	23.3	25.4	27.5
31	88	0.0	2.2	4.5	6.7	9.0	11.2	13.4	15.7	17.9	20.2	22.4	24.6	26.9	29.1
32	90	0.0	2.4	4.7	7.1	9.5	11.9	14.2	16.6	19.0	21.3	23.7	26.1	28.4	30.8
33	91	0.0	2.5	5.0	7.5	10.0	12.5	15.0	17.6	20.1	22.6	25.1	27.6	30.1	32.6
34	93	0.0	2.7	5.3	8.0	10.6	13.3	15.9	18.6	21.2	23.9	26.5	29.2	31.8	34.5
35	95	0.0	2.8	5.6	8.4	11.2	14.0	16.8	19.6	22.4	25.2	28.0	30.8	33.6	36.4

Greenhouse Cooling Relationships



Effect of Light

As light increases, the air temperature rises, relative humidity falls, and VPD, irrigation demand, and evapotranspiration rates climb.

Supplementary Evaporative Cooling

Ventilation (when outside air is cooler)

Ventilation and evaporative cooling work well together since they both tend to increase cooling, while balancing the other climate effects.

Air-Energy System used to control VPD while conserving CO_2 and heat energy

Moist air exchanged for drier air and then distributed throughout the house and circulated via HAF

Match fruit load to carrying capacity of the plant & desired fruit size

Good pollination is the essential first step

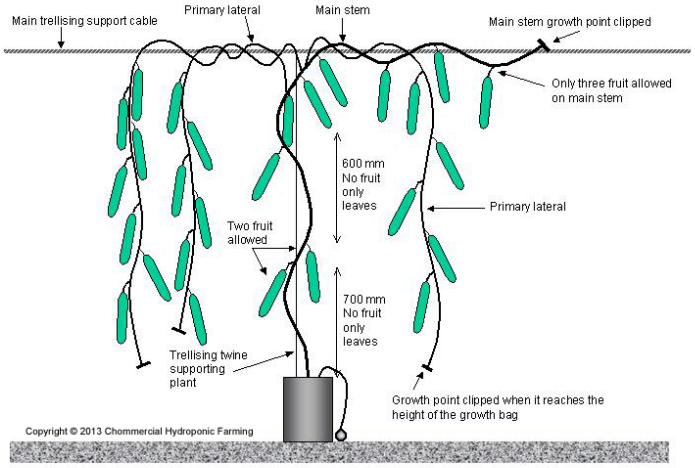
You can prune off fruit to manage fruit load & fruit size

If plants are too vegetative – you can prune off leaves and allow plants to carry more fruit

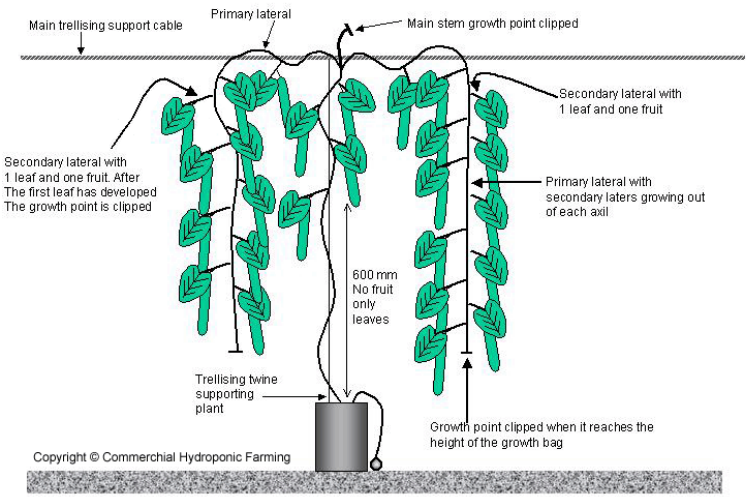
Use of Grafted Rootstock to increase plant vigor

.... grafted rootstock increase the POTENTIAL for consistently higher yields.

Culture and physical management to match plant vigor



The High Pruning system



The Umbrella Renewal System

Example, for Cucumbers

Planting Season	Leaves to 1st fruit	Fruit on main stem
Winter planting (Dec, Jan, Feb)	10-12	3-4
Spring/Summer (Apr. May, Jun)	8-10	5-8
Late fall (Oct, Nov.)	10-12	3-4

By managing fruit load you avoid boom-bust production cycling & maintain fruit quality

Matching Irrigation & Fertility to the prevailing Environmental Conditions

As light (& temperature) increase, water uptake also increases

Irrigation frequency should increase

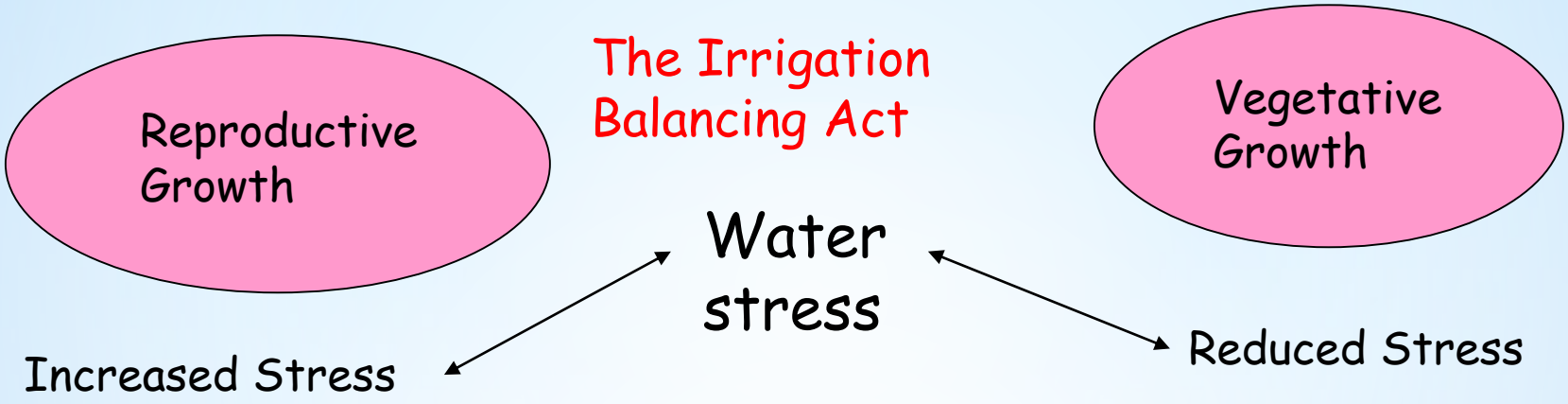
Irrigation = daily adjustment

Fertilization = adjusted based on season & stage of development

Nutrient solution concentration should decrease during the warm, bright season

Monitor Nutritional & Water Status Regularly

Both water & fertility are used to control plant growth, and the tendency toward either vegetative or reproductive (flowering & fruiting) development



Irrigation: rules of thumb

- 8-10% dry down = Vegetative Growth
- 17% dry down = reproductive growth

- Adjust water stress throughout the day (wetter early, drier later)
- Adjust water frequency to weather conditions & plant size
- Frequent, light irrigation cycles are best
- Avoid chronic over or under watering & daily extremes

Manage fertilizer (nutrition) according to the stage of plant development & seasonal conditions

Tomato

- Prior to first flower: run K:N ratio of 1:1 to build the vegetative plant structure
- 1st cluster to 4th: run K:N ratio of 1.5:1
- Mature fruit to ripening: run K:N ratio of 1.7:1
- To boost vegetative growth at any time: increase N proportion especially ammonium (NH_4) form (lowering the K:N ratio), and increase Ca & Mg

Cucumber fertilizer program is adjusted according to stage of development (similar to tomato)

- Transplant to 4-6 leaf stage
- Normal feed for moderate production season
- Heavy fruiting feed schedule for high light season

Nitrogen form: NH_4:NO_3 ratio

- To boost vegetative growth at any time: increase nitrogen proportion especially ammonium (NH_4) form
- Typically keep NH_4 to 10% of total N or less but can increase it more in the short term

Total fertility (EC) levels can be used to modulate stress & alter vegetative or reproductive response and fruit quality

Change total fertility level with seasonal light conditions

- In early Spring & Fall, higher EC (2.5-3.5)
- In Summer, lower EC (1.5-2.5)

Grower Experience is the most important factor of all:

Learning to Read the Plant

Identify problems early and make the proper adjustments quickly

For example, here is what we look for in tomato :

- Leaves appear bright under low water stress & duller under moderate water stress
- Thick stem (1/2" at 6" from the top; thicker = too vegetative, thinner= too much stress)
- Leaves should be closely spaced, expand rapidly & deep green in color
- Flowers & fruit should set easily