Growing Greenhouse Tomatoes & Greenhouse Cucumbers in Containers

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Trends in Greenhouse Tomato Yields:
~1975 top commercial yields about 100 tons per acre per year (20 #/plant*)
~1990 top commercial yields about 200 tons per acre per year (40 #/plant*)
~2005 top commercial yields about 330 tons per acre per year (66 #/plant*)

*Based on 10,000 plants per acre.
Achieved through intense environmental & crop management techniques to maximize the productive potential of the plant.

Environmental & Cultural Factors that are Critical to Crop Production
- Light - quantity, photoperiod, quality
- Temperature
- Water
- Fertility
- VPD or humidity - (to control disease & water use)
- Plant care
- Interaction of all above = crop management
The Umbrella Renewal System

The High Pruning system

Supplemental Lighting Can Boost Yields

Supplemental CO₂ can also boost yields and compensate for limited light.

Rule of Thumb:
1% Increase in Light = 1% Increase in Yield

Rule One: Optimize Available Light
Adjusting to the Light Environment:
Example – The Case of Limited Light
- Plant Density – more area per plant
- Fruit Load – carry fewer fruit
- Temperature – run cooler temperatures
- Irrigation – reduce quantity
- Fertility – higher EC
- VPD – maintain VPD above 0.03 psi to prevent disease (see http://ohioline.osu.edu for fact sheet on VPD)

If you can’t alter the light, then you have to adjust your management to optimize the light that is available.

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**Plant Spacing:** Provide more space in light-limited months

**Adjust Plant Density to Optimize Fruit Quality**

<table>
<thead>
<tr>
<th>Season</th>
<th>Tomato</th>
<th>Cucumber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-limited</td>
<td>5-6</td>
<td>8</td>
</tr>
<tr>
<td>Light-abundant</td>
<td>4-5</td>
<td>6</td>
</tr>
</tbody>
</table>

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**Rule Two:**
Match temperature to the prevailing light environment

**Temperature Controls the Rate of Plant Metabolism & Growth**

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**The Short-Term Temperature Environment**

Adjust night temperature to the light condition of the preceding day

**Tomato**

- During light-limited seasons:
  - Run 60F following dark days
  - Run 63F following bright days
- During light-abundant seasons:
  - Run 62F following dark days
  - Run 65F following bright days

**Cucumber**

- During light-limited seasons:
  - Run 62F following dark days
  - Run 64F following bright days
- During light-abundant seasons:
  - Run 66F following dark days
  - Run 70F following bright days
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Excessive Heat during the day will Stress the Plant

Fan & Pad System has the Potential to Lower Air Temperature to the Dew Point

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Shade in the Brightest Part of the day can Limit Plant Water Stress

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For tomato it all starts with pollination.

- For many it all starts with pollination.
- Number of atomic fruit is highly correlated with final fruit size.
- Each pollen grain produces a single seed.

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Cukes can be gynoecious parthenocarpic (all female flowers that do not need pollination)

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Manage Fruit Load to Match Seasonal Light Levels

You can prune clusters or fruit (on cukes) to manage load, quality & size (on tomatoes)

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<table>
<thead>
<tr>
<th>Cucumber</th>
<th>Leaves to 1st fruit</th>
<th>Fruit on main stem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter planting</td>
<td>10-12</td>
<td>3-4</td>
</tr>
<tr>
<td>(Dec, Jan, Feb)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring/Summer</td>
<td>8-10</td>
<td>5-8</td>
</tr>
<tr>
<td>(Apr, May, Jun)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late fall</td>
<td>10-12</td>
<td>3-4</td>
</tr>
<tr>
<td>(Oct, Nov.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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Start by getting rid of the junk & do it early in development

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'May-Check' in Tomato Fruit Set

A drop in fruit set following heavy flowering & fruit set in March & April

Avoiding or reducing a drop off in production requires a total management approach: temperature, fruit load, fertility & water management

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Both Water & Fertility Can Influence the Tendency Toward Either Vegetative Growth or Reproductive (Flowering & Fruiting)

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The Irrigation Balancing Act

Reproductive Growth

Water Quantity & Frequency

Vegetative Growth

Increased Stress

Reduced Stress

Too Little

Too Much

BER

High Quality Fruit

Cucumber under stress: similar symptoms can occur from water stress, stem rot, or excessive fruit load
Nutrient requirements are related to the stage of plant development & seasonal conditions

- 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 nitrogen proportion especially ammonium (NH₄) form

Cucumber

Similar to tomato, fertilizer program is adjusted for three stages in production:
- Transplant to 4-6 leaf stage
- Normal feed
- Heavy fruiting

Cucumber compared to Tomato

- Very high potassium requirement
- Very high magnesium requirement
- High calcium requirement

Typically use a 4-18-38 base formula supplemented with K₂SO₄, MAP (K₂HPO₄), calcium nitrate, potassium nitrate and ammonium nitrate.

Nitrogen form: NH₄:NO₃ ratio

- To boost vegetative growth at any time: increase nitrogen proportion especially ammonium (NH₄) form
- Typically keep NH₄ to 10% of total N or less but can increase it more in the short term

Total fertility level

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

Matching Irrigation & Fertility with Environment

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

Irrigation frequency should increase

Nutrient solution concentration should decrease

Rule Four: Match Irrigation & Fertility to Prevailing Light Environment

Natural daily PAR available in the greenhouse

Irrigation-daily adjustment

Fertilization-seasonal or stage of development adjustment
Smaller the Root volume the less buffered the system is to Changes in both Nutrient status & Water Status. So choose your System wisely (e.g. to fit your management ability & time constraints).

Some General Rules:
- Smaller the root volume the less buffered it is to change (pH, EC)
- Inert media are less buffered against change than Peat-lite & soil-based media
- As buffering decreases, the need to closely monitor & manage nutrition increases
- Small root volumes allow for better control of crop growth & development BUT only if you are able to monitor and manage closely.

Monitor Nutritional & Water Status Regularly

Use of Grafted Rootstock to Control Plant Vigor …

Grafted rootstock increases the POTENTIAL for Consistently Big Yields.

With Use of Rootstock like "Maxifort", growers can find the Challenge of "Reining in Excessive Vigor" more of a Management issue than "Avoiding Loss of Vigor".

Cucumbers are also grafted but for disease resistance.

Use Superior Root-Stock for Increased Vigor...
The most important factor of all is Grower Experience:

Identify problems early and make the proper adjustments quickly

- 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

Nuts & bolts of building a fertilizer program

- Selecting fertilizers
- Determining concentrations
- Adjusting concentrations
- Calculating ratios

General requirements:

Typical ranges for nutrients (ppm)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>N (NO₃/NH₄)</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>Ca</th>
<th>S</th>
<th>Mg</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>50-100 ppm</td>
<td>300</td>
<td>150</td>
<td>100</td>
<td>25</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>Cucumber</td>
<td>30-60 ppm</td>
<td>150</td>
<td>75</td>
<td>150</td>
<td>25</td>
<td>25</td>
<td>5</td>
</tr>
</tbody>
</table>

Example of a simple fertilizer program:

EC=1.3, K/N ratio=1.6

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>N (oz/100 gal)</th>
<th>P</th>
<th>K</th>
<th>Mg</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrosol</td>
<td>1/2</td>
<td>30</td>
<td>50</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>Calcium nitrate (15.5-0-0)</td>
<td>1/2</td>
<td>25</td>
<td>50</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>Potassium nitrate 13.0-0-44</td>
<td>1/2</td>
<td>25</td>
<td>50</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>Totals</td>
<td>1/2</td>
<td>100</td>
<td>150</td>
<td>75</td>
<td>21</td>
</tr>
</tbody>
</table>

Example of a program with same K/N ratio but lower EC:

EC=1.0, K/N ratio=1.6

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>N (oz/100 gal)</th>
<th>P</th>
<th>K</th>
<th>Mg</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrosol</td>
<td>1/4</td>
<td>20</td>
<td>50</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>Calcium nitrate (15.5-0-0)</td>
<td>1/4</td>
<td>15</td>
<td>50</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>Potassium nitrate 13.0-0-44</td>
<td>1/4</td>
<td>15</td>
<td>50</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>Epom salts</td>
<td>1</td>
<td>10</td>
<td>20</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Ferribide (10%)</td>
<td>1/10</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>1/4</td>
<td>50</td>
<td>100</td>
<td>30</td>
<td>9</td>
</tr>
</tbody>
</table>
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**Example of a program with same EC but lower K/N ratios:**

EC = 2.3  K/N ratio = 1.3

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>N (oz/100 gal)</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrosol (5-11-26)</td>
<td>1.5</td>
<td>50</td>
<td>15</td>
<td>63</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td>Calcium nitrate (15.5-0-0)</td>
<td>10</td>
<td>2.5</td>
<td>243</td>
<td>8</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Ammonium nitrate (14-0-0)</td>
<td>0.5</td>
<td>12</td>
<td>53</td>
<td>53</td>
<td>53</td>
<td>5</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>184</strong></td>
<td>31</td>
<td>241</td>
<td>35</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

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**Example: same as original formulation using a different base formulation:**

EC = 2.3  K/N ratio = 2.3

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>N (oz/100 gal)</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chem-gro (4-18-38)</td>
<td>11</td>
<td>31</td>
<td>63</td>
<td>20</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Calcium nitrate (15.5-0-0)</td>
<td>12</td>
<td>12</td>
<td>249</td>
<td>53</td>
<td>53</td>
<td>53</td>
</tr>
<tr>
<td>Potassium nitrate (13-0-44)</td>
<td>1</td>
<td>10</td>
<td>27</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Epsom salts</td>
<td>6</td>
<td>6</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>181</strong></td>
<td>63</td>
<td>286</td>
<td>63</td>
<td>63</td>
<td>63</td>
</tr>
</tbody>
</table>

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**Tomato nutrition programs used in different regions:**

<table>
<thead>
<tr>
<th>Region</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
<th>Ca (%)</th>
<th>Mg (%)</th>
<th>Fe (%)</th>
<th>K/N Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada (closed)</td>
<td>165</td>
<td>44</td>
<td>78</td>
<td>64</td>
<td>110</td>
<td>58</td>
<td>1.5/1</td>
</tr>
<tr>
<td>Arizona</td>
<td>144</td>
<td>42</td>
<td>62</td>
<td>199</td>
<td>165</td>
<td>50</td>
<td>2.5</td>
</tr>
<tr>
<td>Mississippi (spring)</td>
<td>171</td>
<td>48</td>
<td>304</td>
<td>180</td>
<td>48</td>
<td>3</td>
<td>1.8/1</td>
</tr>
<tr>
<td>Mississippi (summer)</td>
<td>132</td>
<td>36</td>
<td>228</td>
<td>135</td>
<td>36</td>
<td>2.25</td>
<td>1.8/1</td>
</tr>
<tr>
<td>Connecticut (spring)</td>
<td>200</td>
<td>53</td>
<td>323</td>
<td>150</td>
<td>45</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td>Connecticut (hot &amp; tops thinning)</td>
<td>160</td>
<td>42</td>
<td>220</td>
<td>120</td>
<td>56</td>
<td>43</td>
<td>3</td>
</tr>
</tbody>
</table>

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**How to use the look-up table:**

1. Select the base fertilizer you are using (e.g. Hydro Sol 5-11-26, Chem-gro 4-18-38).
2. Find the row that provides all of the N (%) (phosphorus) you need.
3. Step 1 and up calcium nitrate to find the row that provides all of the Ca (%) (calcium) you need.
4. Subtract by adding up all the nutrients, all the N, all the P, etc. (potassium, etc. is not needed).
5. Calculate EC ratio (total N divided by total P) – you can also estimate EC by totaling all of the nutrients together (total ppm), divide this number by 680 and then add the EC of your water.
6. Add other fertilizers such as Epsom salts to supplement Mg (magnesium) or increase potassium as needed.
7. To increase plant vigor (increase nitrogen & lower K/N ratio), by increasing calcium nitrate or you can add a small amount of ammonium nitrate.
8. To reduce plant vigor, increase the K/N ratio by increasing the base fertilizer or increasing potassium nitrate.