Growing Greenhouse Tomatoes for Optimum Yield and Quality

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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
Light Drives Plant Growth & Fruit yield

Rule of Thumb:
1% Increase in Light = 1% Increase in Yield
Supplemental Lighting Can Boost Yields

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

Supplemental CO₂ can also boost yields and compensate for limited light.
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/](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.
Plant Spacing: Provide More space in Light Limited Months

Adjust Plant Density to Optimize Fruit Quality (sq.ft./plant)

<table>
<thead>
<tr>
<th>Season</th>
<th>Tomato</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-limited</td>
<td>5-6</td>
</tr>
<tr>
<td>Light-abundant</td>
<td>4-5</td>
</tr>
</tbody>
</table>
Rule Two:

Match Temperature to the Prevailing Light Environment

Temperature Controls The Rate of Plant Metabolism & Growth

![Graph showing total PAR (mol/m²/day) from Nov 15 to Jan 30, with Natural daily PAR available in the greenhouse highlighted.](image-url)
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
Grow-Tubes Boost Temperature In Localized Parts of the Plant ... to Boost Growth & Manage Disease
The trade off of growing cool
Excessive Heat during the Day will Stress the Plant

Fan & Pad System has the Potential to Lower Air Temperature to the Dew Point
Shade in the Brightest Part of the day can Limit Plant Water Stress
Rule Three: Match Fruit Load to Carrying Capacity & Desired Size*

* For tomato it all starts with pollination.

Number of seed per fruit is highly correlated with final fruit size.

Each pollen grain produces a single seed.
Manage Fruit Load to Match Seasonal Light Levels

You can prune clusters to manage load, quality & size (on tomato)
Start by getting rid of the junk & do it early in development
‘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.
Both Water & Fertility Can Influence the Tendency Toward Either Vegetative Growth or Reproductive (Flowering & Fruiting)
The Irrigation Balancing Act

- Reproductive Growth
- Vegetative Growth

Stress

- Increased Stress
- Reduced Stress

High Quality Fruit

Water Quantity & Frequency

- BER
  - Too Little
- Cracking
  - Too Much
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 irrigations are best
- Avoid chronic over or under watering
- Avoid daily extremes
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
- 1<sup>st</sup> cluster to 4<sup>th</sup>: 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
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 & Fall, 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 more 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
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’
Use Superior Root-Stock for Increased Vigor
Grafting Reference sources:

*Grafting guide - Free download*
http://u.osu.edu/vegprolab/research-areas/grafting/resources/grafting-guide/

*Grafting information & presentations*
http://agsyst.wsu.edu/graftingVegetables.html

*List of rootstock varieties*

*Grafted seedlings*
http://www.plugconnection.com/products/mightymato/
The most important factor of all is Grower Experience:
Learning to Read the Plant

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)

Tomato

<table>
<thead>
<tr>
<th>N (NO$_3$/NH$_4$)</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>S</th>
<th>Mg</th>
<th>Fe</th>
<th>K/N Ratio</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>125-225 ppm N</td>
<td>40-60</td>
<td>200-350</td>
<td>120-180</td>
<td>40-140</td>
<td>30-60</td>
<td>3-7</td>
<td>1:1 to 1.7:1</td>
<td>1.5-3.5</td>
</tr>
</tbody>
</table>
Comparing some basic formulations

<table>
<thead>
<tr>
<th>Fertilizer</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><strong>Hydro-Sol</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-11-26</td>
<td>5</td>
<td>11</td>
<td>26</td>
<td>--</td>
<td>4</td>
<td>3.1</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>(5/0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Jack's</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-12-26</td>
<td>5</td>
<td>12</td>
<td>26</td>
<td>--</td>
<td>8.2</td>
<td>6.32</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>(5/0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chem-Gro</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-18-38</td>
<td>4</td>
<td>18</td>
<td>38</td>
<td>--</td>
<td>0.5</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>(3.5/0.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Plantex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-11-31</td>
<td>6</td>
<td>11</td>
<td>31</td>
<td>--</td>
<td>3.5</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>(6/0)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Plantex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-11-27</td>
<td>7</td>
<td>11</td>
<td>27</td>
<td>--</td>
<td>4.8</td>
<td>3.75</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>(6.48/0.52)</td>
<td></td>
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</tr>
</tbody>
</table>
Example of a simple fertilizer program:

\[ EC = 2.3 \quad K/N \, \text{ratio}^* = 1.6 \]

$$\begin{array}{|c|c|c|c|c|c|c|c|}
\hline
\text{Fertilizer} & \text{(oz/100 gal)} & \text{N} & & & & & \\
\hline
\text{Hydrosol} & 14 & 52 & & & & & \\
(5-11-26) & & & & & & & \\
\hline
\text{Calcium nitrate} & 10 & 115 (6\%) & & & & & \\
(15.5-0-0) & & & & & & & \\
\hline
\text{Potassium nitrate} & 3 & 30 & & & & & \\
13-0-44 & & & & & & & \\
\hline
\text{Totals} & & 198 (4\%) & 49 & 307 & 149 & 32 & 3 \\
\hline
\end{array}$$

\[ *K/N \, \text{ratio}=\text{Total } K/\text{Total } N=307/198 \]
Example of a program with same K/N ratio but lower EC:

EC=1.8 , K/N ratio=1.6

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>(oz/100 gal)</th>
<th>N (%NH₄)</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydrosol (5-11-26)</strong></td>
<td>11</td>
<td>41</td>
<td>39</td>
<td>177</td>
<td>0</td>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td><strong>Calcium nitrate (15.5-0-0)</strong></td>
<td>7.5</td>
<td>87 (6%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Potassium nitrate (13-0-44)</strong></td>
<td>2</td>
<td>20</td>
<td></td>
<td>54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Epsom salts</strong></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>--</td>
</tr>
<tr>
<td><strong>Fe-chelate (10%)</strong></td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td></td>
<td><strong>148 (3.8%)</strong></td>
<td>39</td>
<td>231</td>
<td>112</td>
<td>32</td>
<td>4</td>
</tr>
</tbody>
</table>
Example of a program with same EC but lower K/N Ratio:
EC=2.3   K/N ratio=1.3

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>(oz/100 gal)</th>
<th>N (%NH₄)</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>15</td>
<td>56(0%)</td>
<td>53</td>
<td>241</td>
<td>0</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td>Calcium nitrate (15.5-0-0)</td>
<td>10</td>
<td>115 (6%)</td>
<td></td>
<td></td>
<td></td>
<td>149</td>
<td></td>
</tr>
<tr>
<td>Ammonium Nitrate 34-0-0</td>
<td>0.5</td>
<td>12 (50%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>184 (7.5%)</td>
<td>53</td>
<td>241</td>
<td>149</td>
<td>35</td>
<td>3</td>
</tr>
</tbody>
</table>
Example: same as original formulation using a different base formulation:  EC=2.3,  K/N ratio=1.6

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>(oz/100 gal)</th>
<th>N (%NH₄)</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>33 (12%)</td>
<td>63</td>
<td>258</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Calcium nitrate (15.5-0-0)</td>
<td>12</td>
<td>130 (6%)</td>
<td>179</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium nitrate 13-0-44</td>
<td>1</td>
<td>10</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epsom salts</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>44</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>181 (7.2%)</td>
<td>63</td>
<td>286</td>
<td>179</td>
<td>48</td>
<td>3</td>
</tr>
<tr>
<td>Program</td>
<td>N (%NH₄)</td>
<td>P</td>
<td>K</td>
<td>Ca</td>
<td>S</td>
<td>Mg</td>
<td>Fe</td>
</tr>
<tr>
<td>-------------------------------</td>
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<td>-----</td>
</tr>
<tr>
<td>Canada (closed)</td>
<td>165 (8.5%)</td>
<td>38</td>
<td>254</td>
<td>110</td>
<td>48</td>
<td>24</td>
<td>5</td>
</tr>
<tr>
<td>Canada (open)</td>
<td>240 (7%)</td>
<td>58</td>
<td>371</td>
<td>216</td>
<td>141</td>
<td>58</td>
<td>8</td>
</tr>
<tr>
<td>Arizona</td>
<td>144</td>
<td>62</td>
<td>199</td>
<td>165</td>
<td>50</td>
<td>2.5</td>
<td>1.4/1</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 (4%)</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 (7.5%)</td>
<td>42</td>
<td>220</td>
<td>120</td>
<td>56</td>
<td>43</td>
<td>3</td>
</tr>
</tbody>
</table>
How to use the look-up tables:

1. Select the base fertilizer you are using (e.g. Hydro-Sol 5-11-26, Jack’s 5-12-26, Chem-gro 4-18-38)

2. Find the row that provides all of the ‘P’ (phosphorus) you need.

3. Next ‘Look up calcium nitrate’ & find the row that provides all of the ‘Ca’ (calcium) you need.

4. Sub-total by adding up all the nitrogen, all the P, all the K (potassium) etc.

5. Calculate K/N ratio (total K divided by total N) – 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), potassium nitrate to increase potassium & nitrogen 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.