Growing plants in controlled environments, such as greenhouses, is a challenging task. It requires not only adequate planning, but also sound choices of appropriate materials needed for the process. Among the things you will need to think about are using the correct container size, the right fertilizer and growing media. You will need to have knowledge of the kind of water you are dealing with, and many other factors which may affect your project.

At this station, we are only dealing with growing media, water quality, and plant nutrition.

Your water source and quality are very important. You may need to amend it to achieve your goals.

There are several kinds of containerized growing media to choose from. Though many claims suggest that these growing media are good for growing anything under the sun, you should pay attention to their functionality, and to their physical and chemical characteristics.

If you are not satisfied, you may think of mixing different kinds of soils or soilless media to achieve your objectives. Many combinations have been proposed.

You should also be aware that most of these commercial growing media have no intrinsic fertility. You will have to fertilize your plants.
1. Growing Media

For Containerized Production in Greenhouse (table 1)

Four functions for growing media:

1. Allow gas exchange (oxygen, carbon dioxide)
2. Hold water that is available to the plants
3. Create a reservoir of mineral nutrients
4. Provide plant support

Growing media desirable characteristics:

1. Stability (rate of decomposition)
2. Carbon to nitrogen ratio (30:1 or less)
3. Bulk density (the ratio of the mass of dry solids to the volume they occupy)
4. Moisture retention
5. Aeration (10 - 20% air space at field capacity)
6. pH (a measure of the concentration of hydrogen ions.
   (H+) Found in the media solution
   a. Soil based = 6.0 to 6.5
   b. Soilless based = 5.0 to 6.0
7. Cation exchange capacity - CEC (a measure of nutrient holding ability)
Table 1. Percentages of container volume occupied by water and air (at field capacity) for four media in pots, flats, and plugs

<table>
<thead>
<tr>
<th>Containers</th>
<th>6in standard</th>
<th>4in standard</th>
<th>48 cell flat</th>
<th>512 plug</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Peat Moss:1 Vermiculite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water (%)</td>
<td>67.9</td>
<td>75.2</td>
<td>79.5</td>
<td>84.8</td>
</tr>
<tr>
<td>Air (%)</td>
<td>19.0</td>
<td>11.7</td>
<td>7.4</td>
<td>2.1</td>
</tr>
<tr>
<td>1 Peat Moss:1 Rockwool</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water (%)</td>
<td>68.4</td>
<td>76.0</td>
<td>80.5</td>
<td>86.9</td>
</tr>
<tr>
<td>Air (%)</td>
<td>23.4</td>
<td>15.7</td>
<td>11.2</td>
<td>4.9</td>
</tr>
<tr>
<td>3 Pine bark:1 Sand:1 Peat Moss</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water (%)</td>
<td>51.5</td>
<td>57.6</td>
<td>80.5</td>
<td>86.9</td>
</tr>
<tr>
<td>Air (%)</td>
<td>18.9</td>
<td>12.9</td>
<td>9.1</td>
<td>3.6</td>
</tr>
<tr>
<td>1 Natural Soil:1 Peat Moss:1 Sand</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water (%)</td>
<td>47.2</td>
<td>51.2</td>
<td>52.9</td>
<td>54.3</td>
</tr>
<tr>
<td>Air (%)</td>
<td>7.4</td>
<td>3.4</td>
<td>1.7</td>
<td>0.3</td>
</tr>
</tbody>
</table>

- Plants roots need airspaces in the media;"10-20% air is ideal.
- In a smaller container, the % air diminishes.
**Components of Media (tables 2a & 2b)**

1. Field Soil - High CEC, heavy, high moisture retention, poor air exchange in containers, good source of micronutrients, watch for herbicides.

2. Peat Moss - High CEC, light, decomposes slowly; no nitrogen tie-up tremendous water retention, acidic, needs help with air exchange.

3. Bark - Needs to be composted at least 30 days, may need, Medium CEC, supplemental nitrogen during decomposition, good air exchange.

4. Sawdust - Must be decomposed with 24 lbs of N/ton of sawdust for 30 days or more, decomposes rapidly, fair CEC after decomposing.

5. Vermiculite - Rock that has been heat treated, high CEC, good water retention, source of CA, K, Mg, fair to good aeration.

6. Calcined Clay - Clay that is compressed and then heated, high bulk density, good aeration and drainage CEC of about 20 meq.

7. Sand - Use only a coarse grade, high bulk density, good drainage, poor water retention, poor CEC, use only washed sand.

8. Perlite - Volcanic rock that has been heat treated, used to increase aeration and drainage, light, no CEC, no pH buffering, a good substitute for sand when light weight is desired.


10. Styrofoam - sold as "peanuts", provides drainage but is otherwise inert; may have environment concerns.
Table 2a: Organic amendments used in growing media

<table>
<thead>
<tr>
<th>Amendment</th>
<th>Source</th>
<th>Size</th>
<th>Weight</th>
<th>Useful Life</th>
<th>pH</th>
<th>CEC</th>
<th>Sterile/Contaminants</th>
<th>C/N Ratio</th>
<th>% Recommended (by Volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphagnum peat moss (best quality)</td>
<td>min. 70% sphagnum peat bogs (Germ., Can., Ire.)</td>
<td>fine to coarse</td>
<td>light</td>
<td>3-5 yrs</td>
<td>acidic 4-5.5</td>
<td>high</td>
<td>relatively sterile/none</td>
<td>med</td>
<td>25-75%</td>
</tr>
<tr>
<td>hypanaceous peat moss or domestic peat moss, (med quality)</td>
<td>hypanaceae or sedge peat bogs (northern U.S.)</td>
<td>intermediate</td>
<td>light</td>
<td>2-3 yrs</td>
<td>acidic 4.5-5.5</td>
<td>high</td>
<td>relatively/none</td>
<td>med</td>
<td>25-75%</td>
</tr>
<tr>
<td>muck peat moss (poor quality)</td>
<td>highly decomposed peat/plant bogs (southern U.S.)</td>
<td>very fine</td>
<td>light</td>
<td>short, 1 season</td>
<td>acidic 4.5-5.5</td>
<td>high</td>
<td>---</td>
<td>med</td>
<td>25-50%</td>
</tr>
<tr>
<td>Bark (shredded or ground)</td>
<td>hardwood &amp; softwood tree species</td>
<td>fine to coarse</td>
<td>med</td>
<td>3-5 yrs</td>
<td>4-5.5</td>
<td>med</td>
<td>No/resins</td>
<td>med</td>
<td>25-75%</td>
</tr>
<tr>
<td>sawdust or wood shavings</td>
<td>hardwood &amp; softwood tree</td>
<td>fine to coarse</td>
<td>light</td>
<td>3-5 yrs; spp. depend.</td>
<td>4.8-6.8 spp. Depend.</td>
<td>med</td>
<td>no/some resins</td>
<td>very high</td>
<td>25% max</td>
</tr>
<tr>
<td>cedar chips</td>
<td>cedar heart wood chips after oil is extracted</td>
<td>coarse</td>
<td>med</td>
<td>as sawdust</td>
<td>6.0</td>
<td>low</td>
<td>relatively/resins,oil</td>
<td>high</td>
<td>25% max</td>
</tr>
<tr>
<td>bagasse</td>
<td>sugar cane pulp</td>
<td>variable</td>
<td>light</td>
<td>1-3 yrs (composted)</td>
<td>acidic</td>
<td>med</td>
<td>no/sugar</td>
<td>high-very high</td>
<td>25% max</td>
</tr>
<tr>
<td>rice hulls</td>
<td>hulls (shells) of rice</td>
<td>med</td>
<td>very light</td>
<td>1 season</td>
<td>neutral</td>
<td>low-med</td>
<td>no/silica</td>
<td>high</td>
<td>25% max</td>
</tr>
<tr>
<td>processed sewage sludge</td>
<td>municipal sewage treatment plants</td>
<td>very fine</td>
<td>light-med</td>
<td>2-3 yrs</td>
<td>acidic 5.0</td>
<td>med</td>
<td>no (human viruses)/heavy metals</td>
<td>med</td>
<td>25% max</td>
</tr>
</tbody>
</table>

CEC = cation exchange capacity, indicates nutrient holding capacity or potential fertility.
C:N = ratio of carbon to nitrogen. High C/N ratio depletes soil nitrogen; and low C/N ratio releases nitrogen into medium.
Table 2b: Inorganic amendments used in growing media

<table>
<thead>
<tr>
<th>Amendment</th>
<th>Source</th>
<th>Process</th>
<th>Size</th>
<th>Weight (lb/ft³)</th>
<th>Useful Life</th>
<th>pH</th>
<th>CEC*</th>
<th>Sterile / Contaminants</th>
<th>% Recommended (by Volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perlite</td>
<td>aluminum-silica volcanic rock</td>
<td>crush; heated to 1800°F to expand</td>
<td>use horticultural grade</td>
<td>4-8</td>
<td>infinite, unless crushed</td>
<td>7.0-7.5</td>
<td>none</td>
<td>yes/fluoride (F)</td>
<td>25-50%</td>
</tr>
<tr>
<td>Vermiculite</td>
<td>mica mineral</td>
<td>crush; heated to 1400°F to expand</td>
<td>use horticultural grade (#2,3, or 4)</td>
<td>4-10</td>
<td>use media only once compresses easily when wet</td>
<td>Amer.-7.5 S. Afr.-9.8</td>
<td>very high</td>
<td>yes/6% K (K2O), 20% Mg (MgO)</td>
<td>25-50%</td>
</tr>
<tr>
<td>Styrofoam beads (polystyrene)</td>
<td>polystyrene</td>
<td>by-product of polystyrene processing</td>
<td>variable, use 1/4 to 1/2 inch</td>
<td>very light</td>
<td>infinite, unless heated or disinfected</td>
<td>neutral</td>
<td>none</td>
<td>yes-none</td>
<td>25-50%</td>
</tr>
<tr>
<td>sand</td>
<td>sand pits, dunes or river bottoms</td>
<td>dug &amp; washed</td>
<td>use coarse, sharp sand, 0.25-0.5 is best</td>
<td>100</td>
<td>infinite</td>
<td>variable mostly neutral</td>
<td>very low</td>
<td>no-none if well washed</td>
<td>25-25%</td>
</tr>
<tr>
<td>calcined clay or haydite</td>
<td>montmorillonite &amp; attagulgite clays</td>
<td>grade particles, heat (fired) to 1300°F to harden</td>
<td>variable</td>
<td>38</td>
<td>virtually infinite</td>
<td>---</td>
<td>med-high</td>
<td>non-none</td>
<td>20-25%</td>
</tr>
<tr>
<td>rice hull ash</td>
<td>rice hulls</td>
<td>combustion</td>
<td>like fine sand</td>
<td>50-80</td>
<td>infinite</td>
<td>9.3</td>
<td>med-high</td>
<td>97% silica diox</td>
<td>20-25%</td>
</tr>
</tbody>
</table>

• CEC = cation exchange capacity, indicates nutrient holding capacity or potential fertility.

YNOTE: Many of these are sterile after being processed, but may become contaminated later.
Products Commonly used at Walnut Street Greenhouse:

Metro-Mix 366P

- Specially processed coconut coir pith
- Medium vermiculite
- Composted pine bark
- Perlite

Farfard GM #2

- Peat moss
- Perlite
- Vermiculite

Sunshine Mix #1/LCI

- Canadian Sphagnum peat moss
- Coarse Perlite
- Starter nutrient charge (with Gypsum)
- Dolomitic Limestone
2. Water Source and Water Quality

Factors Affecting Water Quality in Greenhouses (Reference Table 3)

1. The pH
Most plants grow best when the media solution pH is 5.6 to 6.2.

The main effect of water pH on plant growth is through control of nutrient availability.

A low pH may be responsible for excess iron and manganese availability leading to toxicity, or calcium and magnesium deficiencies. A high pH may cause iron, manganese, and other minor nutrients to become unavailable to plants, leading to deficiencies.

2. Alkalinity- Carbonates and Bicarbonates
Alkalinity is the concentration of soluble compounds in the water that have the ability to neutralize acids. High alkalinity has a high buffering capacity - it neutralizes added acids. It has much greater effect on plant growth than pH of the Water.

Water hardness is an indication of the amount of calcium and magnesium in the water (MgCO₃)/CaC0₃/1, or parts per million CaC0₃). Water with hardness in the range of 100 to 150 mg MgO₃/CaC0₃/1 is considered desirable for plant growth. Plants tolerate high levels of these elements, so toxicity is not normally a problem.

3. Soluble Salts and Hardness
Soluble salts in water are measured by electrical conductivity (EC) expressed as millimhos per centimeter. Electrical conductivity is also referred to as specific conductance or salinity.

Excess soluble salts impair the proper function of roots, which can lead to reduced water uptake and nutrient deficiencies.

Madison City Water has a high concentration of calcium and magnesium, which results in hard (alkaline) water.
Table 3: Desirable levels of nutrients and other components of irrigation water

<table>
<thead>
<tr>
<th>Water Quality Measurements</th>
<th>Desirable Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.8 to 6.0 (alkalinity matters MUCH more)</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>0.75 - 2.6 meq/1CaC0₃</td>
</tr>
<tr>
<td>Soluble salts (EC)</td>
<td>&lt;1.5 mmhos/cm</td>
</tr>
<tr>
<td>Hardness</td>
<td>100 to 150 mg CaC0₃/1</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>40 to 100 ppm</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>30 to 50 ppm</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>&lt;50 ppm</td>
</tr>
<tr>
<td>Sulfate (SO4)</td>
<td>&lt;50 ppm</td>
</tr>
<tr>
<td>Fluoride (F-)</td>
<td>&lt;0.75 ppm</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>&lt;0.5 ppm</td>
</tr>
</tbody>
</table>

Note: These are ideal levels; acceptable levels may be broader.
3. Plant Nutrition or Fertilization

Twelve elements need to be supplied:

N-P-K, Ca-Mg-S, Fe-Mn-Zn-Cu-B-Mo

These nutrients must be supplied in adequate amounts, in a form the plant can utilize, and in balance with the other nutrients. The proper pH is critical for your nutrition program to be effective.

- Soil based media should have a pH between 6.2 and 6.8
- Soilless media should have a pH between 5.0 and 6.0.
- Irrigation water can change media pH rapidly.

Fertilizer program:
1. Pre-plant incorporated
   a. All 12 nutrients are in the media before planting or transplanting and are expected to last the life of the crop.
   b. Some of the 12 nutrients are in the media prior to transplanting. More common.
2. Provide fertilization at every watering (fertigation)
   a. Can be all 12 nutrients, or only a few
   b. If fertilization is supplied at every watering generally Nitrogen and Potassium are supplied at the rate of 100 PPM to 200 PPM
   c. Fertilization on a weekly basis would use 400 PPM N and/or K or more. It is important to look at the crop and adjust your liquid fertilization program accordingly.
3. Slow release fertilizers
   Plastic-encapsulated fertilizers
   Most common-Many types and forms;
   Can be used with liquid or soil incorporated fertilizers
   Good ("Crop insurance")
   Chelated micronutrients- protected from precipitation
4. Slowly soluble fertilizers

Urea formaldehyde (36% N) can last over one year
Mag Amp (7-40-6) plus 12% Magnesium
Limestone (dolomitic is best)
Gypsum
Sulfur coated fertilizers ("Prills" coated with sulfur, wax sealants and diatomaceous earth) can last up to three or four months -microorganism dependents.

**Nutritional Monitoring:**

1. Visual monitoring - chlorosis, mobility, etc,
2. Soil testing
3. Leaf (foliar) analysis
4. Soluble salts testing
5. pH - can change rapidly; causes more problems in containerized production than lack of nutrients or an imbalance of nutrients
   a. Sulfur, aluminum sulfate, iron sulfate or acidifying fertilizers are used to push the pH down (use about 0.5 pounds of sulfur per cubic yard to lower the pH about 0.5 units).
   b. Dolomitic limestone (fine mesh) or certain fertilizers are used to push the pH up.
   c. Consider an acid injector in areas with high Ca & Mg in the water supply
   d. Consider adding dolomitic lime in the areas of neutral or soft water (3 pounds per cubic yard will raise the pH about 0.5 units).
**Nutritional Interactions:**
1. N in excess competes with or displaces K (and vice versa).
2. Na in excess competes with or displaces K, Ca, Mg.
3. Ca in excess competes with or displaces Mg (and vice versa).
4. Ca in excess competes with or displaces B.
5. Fe in excess competes with or displaces Mn (and vice versa).

**Other Nutritional Problems:**
Certain clays can tie up potassium.
Bark and peat based media are often associated with micronutrient deficiencies (especially iron).
Sources:

