Greenhouse Vegetable Production

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Potential Greenhouse Vegetables

Tomato
Pepper (?)
Cucumber
Leafy greens and lettuces
Strawberry – No!
Others?

Greenhouse Tomato Production

Crops
– Tomatoes
– Cucumbers
– Lettuce
– Strawberry (NO)
Marketing / Economics
Cropping Systems
– Soil Preparation
– Fertility
– Varieties
– Spacing
– Training / Pruning
– Irrigation
Bag Culture / NFT
– Growing Media / Containers
– Varieties
– Spacing
– Training / Pruning
– Support
– Nutrient solution
– Watering Schedule
General
– Temperature Control
– Humidity Control
– Pollination
– Pest Control
– Weeds
– Insects
– Diseases
– Harvesting
– Marketing

Marketing and Economics

Marketing Options
– Wholesale
  • Spring Crop
  • Fall Crop
– Retail
  • Spring Crop
  • Fall Crop
– Greenhouse and Field
  • Long Season (April 1 to December 31)

Greenhouse Tomato Budgets
– Several Available
  • Mississippi State
  • British Columbia
  • ARE Report No. 18
– Best
  • ARE Report No. 18
  • Mississippi State
Greenhouse Tomato Budgets

New 24’ X 96’ GH plus Labor and Equipment
- Total Price
  - $16,335
- Depreciated
  - $1,914 / year

Annual Production Costs
- $9,581
- Operating
  - $6,620
- Capital
  - $721
- Misc.
  - $2,240

Greenhouse Tomato Budgets (cont.)

Gross Returns
- 8,400 lb
- $1.57 / lb
- $13,188
  - 840 lb @ $1.90 / lb
  - 5,880 lb @ $1.60 / lb
  - 1,680 lb @ $1.30 / lb

Net Returns
- Existing House
  - $3,607
    - Gross Returns
      - $13,188
    - Annual Costs
      - $9,581
- New House
  - $1,693
    - Establishment Costs
      - $1,914

Greenhouse Tomato Production

Production Systems
- Soil Culture
  - Most room for error
- Bag Culture
  - Moderate room for error
- Nutrient Film Technique (NFT)
  - No room for error
Cropping Systems – Approach 1

Fall Crop
- Start Seed
  July 1st
- Transplant
  August 15th
- First Harvest
  Mid – October
- End Crop
  Mid – late December

Spring Crop
- Start Seed
  Thanksgiving - Christmas
- Transplant
  Mid – January – mid – February
- First Harvest
  Late March – mid – April
- End Crop
  July 1st

Cropping Systems – Approach 2

10 Month Crop
- Start Seed
  July 1st
- Transplant
  August 15th
- First Harvest
  Mid – October
- End Crop
  July 1st

Concerns
- Vine Health
- Fertility
- Diseases
- Insects
- Heat Bills
- Light Intensity

Soil Culture Production Practices

Very similar to field tomato production!

Soil Preparation and Planting

Remove and/or incorporate crop residue
Work soil as deeply as possible
Fumigate – Biofence?
Form ridges or small beds
Set plants
Lay irrigation tubing
Cover the middles with plastic
**Greenhouse / Soil Production**

**pH and Fertility**

**pH**
- Range of 6.0 – 6.8
  - 6.5
    - Good nutrient availability
    - Reduced incidence of Fusarium Wilt
- Less than 5.5
  - Nutrient deficiencies
  - Nutrient toxicities
- Greater than 6.8
  - Nutrients become unavailable

**Fertility – Bareground Tomatoes**

- **Nitrogen (N)**
  - 175 – 200 lb/A total
    - 25 – 60 lb/A at planting
    - 1 to 1.5 lb/A/day beginning 3 weeks after transplanting
- **Phosphate (P₂O₅)**
  - Low 240 lb/A  Medium 120 lb/A  High 60 lb/A
- **Potash (K₂O)**
  - Low 240 lb/A  Medium 120 lb/A  High 60 lb/A

**Fertility (30’ x 96’ = 2,880 ft²)**

- **Nitrogen (N)**
  - 16 – 20 lb/GH total
    - 3 – 6 lb/GH at planting
    - 0.06 to 0.1 lb/GH/day beginning 3 weeks after transplanting
- **Phosphate (P₂O₅)**
  - Low 24 lb/GH  Medium 12 lb/GH  High 8 lb/GH
- **Potash (K₂O)**
  - Low 24 lb/GH  Medium 12 lb/GH  High 8 lb/GH
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**Fertility – Example (Medium)**

- Apply 6 – 12 – 12 prior to transplanting
  - 100 lb of 6 – 12 – 12 / GH
  - 50 lb of 12 – 24 – 24 / GH
- Three weeks after transplanting begin applying N, Ca, and K₂O every week (2 to 3 – 4 lb/A/day)
  - 5 – 15 lb of Calcium Nitrate / GH
  - 5 – 15 lb of Potassium Nitrate / GH
  - 5 – 15 lb of Soluble 20 – 20 – 20 / GH
  - Alternate the 3 products

**Too Much Nitrogen or Low Light**

**Nitrogen Deficiency**

**Potassium Deficiency**
Phosphorus Deficiency

Calcium Deficiency

Magnesium Deficiency

Varieties

Determinate
- ‘BHN 589’
- ‘BHN 871’
- ‘Biltmore’
- ‘Carolina Gold’
- ‘Empire’
- ‘Rocky Top’ (?)

Indeterminate
- ‘Big Beef’
**Practical Guide to Variety Selection**

Identify a variety that satisfies your market requirements.
Learn how to grow that variety to maximize yield and quality.
- Researchers
- Extension
- Other growers
- Your own records

**Plant Population**

- 30’ x 96’ GH
- Use 30’ x 90’
- 9 – 10 rows
- 60 plants / row @ 18” spacing
- 540 – 600 plants

**Tomato Plant Spacing**

**Between-Row**
- Dictated by the equipment used
- As close as you can stand them
  - 3 ft. – 4 ft.
  - 3.5 ft. (42 in.)

**In-Row**
- Dictated by:
  - Variety
  - Training System
- Determinate variety pruned to 2 stems
  - 1.5 ft. – 2 ft.
- Indeterminate variety pruned to a single stem
  - 12 in. – 18 in. (15 in.)

**Pruning / Training**

**Determinate**
- Leave the first sucker below the first fruit cluster
- Remove most or all other suckers as the plant matures
- When plants extend above the stakes, break out the growing point

**Indeterminate**
- Prune to a single stem
- Remove all suckers up the plant
- Do not over-sucker the top of the plant
- Make sure the plant doesn’t terminate
Irrigation

When first transplanted, tomatoes require about 1 in. of water/A/week. When developing fruit, tomatoes require between 2 and 2.5 in. of water/A/week.

30’ x 96’ Greenhouse
- 1,000 gallons/week at transplanting
- 2,000 to 2,500 gallons/week at ‘full load’

Growing Media / Containers

Media
- Perlite
- Ground Pine Bark
- Misc. Materials
  - Coconut Hull
  - Cotton Gin Trash

Containers
- Upright Bags
- Flat Bags
- Buckets
- Pots

Bag Culture / NFT

Varieties

Recommended
- ‘Trust’
- ‘Match’
- ‘Switch’
- ‘Blitz’
- ‘Cobra’
- ‘Bigdena’ (trial)
- ‘Brightina’ (trial)
- ‘Panzer’ (trial)
- ‘Big Beef’ (?)
### Tomato Plant Spacing

**Between Row**
- Double row configuration on 5 ft. centers
- Approximately 1 ft. between each double row

**In-row**
- Fall Crop 16 in.
- Spring Crop 14 in.
- Compromise 15 in.
- Depends on the container used!

### Plant Population

**30’ x 96’ GH**
- Use 30’ x 85’
- 5 double rows (10 rows)
- 72 plants/row @ 14”
- 64 plants/row @ 16”
- 640 – 720 plants
- 3.5 – 4 ft²/plant

### Planting Configuration

- Use 30’ x 85’
  - 5 double rows (10 rows)
  - 72 plants/row @ 14”
  - 64 plants/row @ 16”
  - 640 – 720 plants
  - 3.5 – 4 ft²/plant

### Training / Pruning

- **Indeterminate**
  - Prune to a single stem
  - Remove all suckers up the plant
  - Do not over-sucker the top of the plant
  - Make sure the plant doesn’t terminate

- **Cluster Pruning**
  - Reduces the number of fruit / cluster
  - Increases the size and quality of fruit
  - Increases uniformity of fruit ripening
  - Typically 4 to 5 (6) good fruit/cluster
Cluster Pruning

Support
- Greenhouse itself
- Separate frame
- Provide overhead support - wire
- Nylon twine
  - Clipped to base of the plant
  - Tied to a wire or cable

Nutrient Solution – Modified Steiner (ppm)

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration</th>
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<tbody>
<tr>
<td>N</td>
<td>171 ppm</td>
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<tr>
<td>P</td>
<td>48 ppm</td>
</tr>
<tr>
<td>K</td>
<td>304 (+10% ‘Trust’) ppm</td>
</tr>
<tr>
<td>Ca</td>
<td>180 ppm</td>
</tr>
<tr>
<td>Mg</td>
<td>48 ppm</td>
</tr>
<tr>
<td>Fe</td>
<td>3 ppm</td>
</tr>
<tr>
<td>Mn</td>
<td>1 – 2 ppm</td>
</tr>
<tr>
<td>B</td>
<td>1 ppm</td>
</tr>
<tr>
<td>Zn</td>
<td>0.4 ppm</td>
</tr>
<tr>
<td>Cu</td>
<td>0.2 ppm</td>
</tr>
<tr>
<td>Mo</td>
<td>0.1 ppm</td>
</tr>
</tbody>
</table>
Percentage of Modified Steiner

**Fall Crop**
- Transplant to 1st bloom on 4th cluster
  - 40 – 50%
- Above to end of crop
  - 85 – 90%

**Spring Crop**
- Transplant to 1st bloom on 4th cluster
  - 40 – 50%
- Above to 1st bloom on fifth cluster
  - 85 – 90%
- Above until May 1
  - 100%
- Above until June 1
  - 75%
- Above until end of crop
  - 60%

pH

The pH of the fertilizer solution should be between 5.6 and 5.8
- Nutrient availability
- To prevent the formation of calcium phosphate

pH Adjustment
- Most water is above pH 6
- Acid to lower the pH
  - Sulfuric
  - Nitric
  - Hydrochloric
  - Phosphoric

Mixing Fertilizer

**Bulk Tank**
- All components are diluted and added to a bulk tank
- The tank has the appropriate concentration of each nutrient
- Solution is used directly and not diluted further

**Multiple Injectors**
- Each component is mixed in a concentrated solution
- As the plants are watered, the concentrate is diluted and mixed

Fertilizer Components

**Tank A**
- Complete Fertilizer
  - N
  - P
  - K
- Micro-Nutrients
- Epson Salts (?)

**Tank B**
- Calcium Nitrate
- Potassium Nitrate (?)
Injection System

Sources of Water Soluble Fertilizers

- Complete
  - Hydro-Gardens Chem-Gro Tomato Formula
    - 4 – 18 – 38
  - Champion GH Tomato
    - 3 – 15 – 28
  - TotalGro Bag Culture Tomato Special
    - 3 – 13 – 29

- Greenhouse Grade Calcium Nitrate
  - Hydro-agri (Viking Ship)

- Potassium Nitrate
  - Champion
  - Hiafa

- Epson Salts

Keep in Mind

There is no exact “recipe” greenhouse tomato production
- Each crop is different
  - Light intensity
  - Temperature
  - Etc.

Three Important “Tools”

- pH Meter
  - Buffer solution to calibrate

- EC Meter
  - Standard to calibrate

- Tissue Test
  - Take the leaf just above a fruit that is 2 inches in diameter (golf ball size)

- Labs
  - Mississippi State University
    - Soil Testing and Plant Analysis, P.O. Box 9610, Mississippi State, MS 39762
  - Private Labs
    - Micro-Macro, Athens, GA
    - A & L, Memphis, TN
Tissue Testing

Since there is no exact recipe and each crop is different, periodic tissue testing should be utilized.
- Routine
- Problem Solving

How to sample for a Leaf Tissue Analysis
- Collect at least 6 to 8 (10 – 12) leaves from different plants.
- Collect the leaf just above a 2” diameter fruit (golf ball size).
- Higher of lower will not be accurate

Elemental Concentrations of Tomato Leaf Tissue

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>4.0 – 5.5 %</td>
</tr>
<tr>
<td>P</td>
<td>0.3 – 1.0 %</td>
</tr>
<tr>
<td>K</td>
<td>4.0 – 7.0 %</td>
</tr>
<tr>
<td>Ca</td>
<td>1.0 – 5.0 %</td>
</tr>
<tr>
<td>Mg</td>
<td>0.4 – 1.5 %</td>
</tr>
<tr>
<td>Fe</td>
<td>100 – 250 ppm</td>
</tr>
<tr>
<td>Zn</td>
<td>30 – 150 ppm</td>
</tr>
<tr>
<td>Mn</td>
<td>40 – 300 ppm</td>
</tr>
<tr>
<td>Cu</td>
<td>5 – 25 ppm</td>
</tr>
<tr>
<td>B</td>
<td>35 – 100 ppm</td>
</tr>
<tr>
<td>Mo</td>
<td>0.15 – 5 ppm</td>
</tr>
</tbody>
</table>

Watering Schedule

Depending on size, temperature, humidity, etc.
Plants will use from:
- 2 oz / day
- 3 quarts / day
- 2 quarts / day is often enough

Rule of Thumb
- 10 – 20% of bags draining after watering

Automated to apply small amounts of water many times / day.
- Time
  30 seconds every hour
- Light accumulation
  30 seconds every 0.8 mhos of light

Temperature Control

Soil Culture
- Minimum night temperature
  50 – 55°F
- Minimum day temperature
  60 – 65°F
- Maximum temperature
  80 – 85°F

Bag / NFT Culture
- Minimum night temperature
  60 – 65°F
- Minimum day temperature
  70 – 75°F
- Maximum temperature
  80 – 85°F
### Humidity Control

Humidity control
- A full canopy of a tomato or cucumber crops will produce significant amounts of moisture through transpiration
- A closed GH maintains that moisture

Humidity control fan in the top of the house works very well.

### Humidity Control (cont.)

As low as possible
- Optimum
  - 60 – 70%
- Realistic
  - 80 – 90%

Humidity control fan
- Switch
- Timer
- Humidistat

### Pollination

Greenhouse tomatoes should be pollinated every other day.
- Hand
- Electric pollinator
- Bees

Low humidity is important

### Pest Control

**Weed Control**
- Soil Culture
  - Black Plastic Mulch
  - Roundup – empty house only
  - Sencor DF and Select

**Disease Control**
- Bag / NFT Culture
  - Should be no weeds

**Insect Control**
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**Disease Control**

**Disease Management**
- Biological
  - Resistant Varieties
- Cultural
  - Humidity Control
  - Temperature Control
  - Fertilization
  - Pruning
- Sanitation
- Chemical
  - Fungicides
  - Bactericides

**Major Diseases**
- Botrytis Gray Mold
- Leaf Mold
- Early Blight
- Powdery Mildew
- Target Spot
- Pythium Root Rot
- Fusarium crown and Root Rot
- Bacterial Pith Necrosis
- Tomato Mosaic Virus
- Tomato Spotted Wilt Virus
- Timber Rot

**Insect Control**

**Major Insects**
- Aphids
- White Flies
- Spider Mites
- Armyworms
- Cabbage Loopers
- Tomato Fruitworm
- Fungus Gnats
- Leaf Miners
- Pinworms
- Slugs

**Mechanical Control**
- Solarization
  - During the summer months
- Reflective (Colored) Mulch
  - Yellow repels aphids
  - Silver repels thrips
- Physical Barriers
  - Aluminum foil, small cans
- Hand Picking
  - Hornworms
- Sweeping

**Biological Insect Control**

**Biological Control**
- Predators
  - Lady Beetle
    - Small, soft bodied insects
  - Ground Beetle
    - Small, soft bodied insects, eggs, worms
  - Lacewing
    - Small, soft bodied insects, eggs, worms
  - Damsel Bug
    - Small, soft bodied insects, eggs, worms
- Parasites
  - Braconid Wasp
  - Encarsia formosa
  - Predatory mites (thrips)
- Diseases
  - Protazoa
  - Bacteria (most effective)
  - Fungi
  - Virus

**Harvesting**

**Pick ripe fruit**
- Better flavor
- More Lycopene
- Better customer satisfaction

**Harvest at least twice a week**
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Marketing

Marketing Options
- Wholesale
  - Spring Crop
  - Fall Crop
- Retail
  - Spring Crop
  - Fall Crop
- Greenhouse and Field (?)
  - Long Season (April 1 to December 31)

Production Systems

Greenhouse Cucumber Production

Production Systems
- Soil Culture
  - Most room for error
- Bag Culture
  - Moderate room for error
- Nutrient Film Technique (NFT)
  - No room for error

Cropping Systems – Approach 1

Fall Crop
- Start Seed
  - August 1st
- Transplant
  - August 18th
- First Harvest
  - Late – September
- End Crop
  - Mid – late December

Spring Crop
- Start Seed
  - Early January – Early February
- Transplant
  - Mid – January – Mid – February
- First Harvest
  - Early March – Early – April
- End Crop
  - July 1st
Cropping Systems – Approach 2

10 Month Crop
- Start Seed August 1st
- Transplant August 18th
- First Harvest Late – September
- End Crop July 1st

Concerns
- Vine Health
- Fertility
- Diseases
- Insects
- Heat Bills
- Light Intensity

Varieties

Beit-Alpha Types
- ‘Mansur’
- ‘Nova’
- ‘Saber’

Long (English) Types
- ‘Discover’
- ‘Roynante’
“Pickles”
- ‘Excelesior’

Growing Media / Containers

Media
- Perlite
- Ground Pine Bark
- Misc. Materials
  - Coconut Hull
  - Cotton Gin Trash

Containers
- Upright Bags
- Flat Bags
- Buckets
- Pots

American Slicers

‘Alcazar’
‘Tamazula’
For trial:
- ‘P08040’
- ‘P08044’
Cucumber Plant Spacing

Between Row
- Double row configuration on 5 ft. centers
- Approximately 1 - 2 ft. between each double row

In-row
- Fall Crop
  24 in.
- Spring Crop
  18 in.
- 5 to 7 ft² / plant
- Depends on the container used?

Plant Population

30’ x 96’ GH
Use 30’ x 85’
- 5 double rows (10 rows)
- 57 plants/row @ 18”
- 43 plants/row @ 24”
- 430 – 570 plants
- 4.5 – 6 ft²/plant

Planting Configuration

```
x x x x x x x x x x x x x x x x x
x x x x x x x x x x x x x x x x
x x x x x x x x x x x x x x x x
x x x x x x x x x x x x x x x x
x x x x x x x x x x x x x x x x
```

Training / Pruning

Modified Umbrella
- Prune to a single stem
- Remove all suckers up the plant to the wire
- Allow two suckers to develop at the wire
- Break out top
- Let suckers grow back toward ground
- Terminate at about 2/3 the distance to the ground
- Allow new suckers to develop

Fruit Pruning
- Remove the bottom 6 to 10 fruit from each main vine
  - Increases vigor of the plants
  - Increases the size and quality of fruit
Support

- Greenhouse itself
- Separate frame
- Provide overhead support - wire
- Nylon twine
  - Clipped to base of the plant
  - Tied to a wire or cable

Nutrient Solution – Seeding to First Fruit (J.B. Jones, 1983)

<table>
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<th>Concentration (ppm)</th>
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<tr>
<td>P</td>
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<tr>
<td>K</td>
<td>150</td>
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<td>Ca</td>
<td>130</td>
</tr>
<tr>
<td>Mg</td>
<td>50</td>
</tr>
<tr>
<td>Fe</td>
<td>2.5</td>
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<tr>
<td>Mn</td>
<td>0.62</td>
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<tr>
<td>B</td>
<td>0.44</td>
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<tr>
<td>Zn</td>
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<tr>
<td>Cu</td>
<td>0.05</td>
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<tr>
<td>Mo</td>
<td>0.03</td>
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Nutrient Solution – First Fruit to Termination (J.B. Jones, 1983)

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<td>Cu</td>
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<tr>
<td>Mo</td>
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Elemental Concentrations of Whole Leaves (J.B. Jones, 1983)

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<td>0.4 – 0.8 %</td>
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<tr>
<td>K</td>
<td>4.0 – 6.0 %</td>
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<tr>
<td>Ca</td>
<td>1.0 – 2.0 %</td>
</tr>
<tr>
<td>Mg</td>
<td>0.5 – 1.0 %</td>
</tr>
<tr>
<td>Fe</td>
<td>60 – 250 ppm</td>
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<tr>
<td>Zn</td>
<td>25 – 75 ppm</td>
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<td>Mn</td>
<td>50 – 200 ppm</td>
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<tr>
<td>Cu</td>
<td>5 – 10 ppm</td>
</tr>
<tr>
<td>B</td>
<td>40 – 60 ppm</td>
</tr>
<tr>
<td>Mo</td>
<td>? ppm</td>
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</table>
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Watering Schedule
- Depending on size, temperature, humidity, etc.
- Plants will use from:
  - 1 quart / day
  - 4 quarts / day
  - 3 quarts / day is often enough
- Rule of Thumb
  - 10 – 20% of bags draining after watering
- Automated to apply small amounts of water many times / day.
  - Time: 30 seconds every hour
  - Light accumulation: 30 seconds every 0.8 mhos of light

Humidity Control
- As low as possible
  - Optimum: 60 – 70%
  - Realistic: 80 – 90%
- Humidity control fan
  - Switch
  - Timer
  - Humidistat

Temperature Control
- Germination
  - 80 – 85°F
- Seedling Development
  - Nighttime: 65°F
  - Daytime: 75 - 80°F
- Optimum Production
  - 75 - 80°F
- Bag / NFT Culture
  - Minimum night temperature: 60 – 65°F
  - Minimum day temperature: 70 - 75°F
  - Maximum temperature: 85 - 95°F

Pollination
- Parthenocarpic Greenhouse Cucumbers
  - Should not be pollinated
  - Pollination will cause the development of seed, causing the fruit to become bitter
Pest Control

Weed Control
Disease Control
Insect Control

Weed Control
– Bag / NFT Culture
  Should be no weeds

Harvesting

Pick fully developed cucumbers
– Longer shelf life
– Better customer satisfaction

Harvest:
– Cool
  Every day
– Hot
  Twice a day

Greenhouse Lettuce Production

Short Season Crop
– Spring and Fall
  28 to 32 days
– Winter
  45 to 60 days
– Varieties
  ‘Flandria’
  ‘Rex’

Germinating Lettuce

Seeding
– Oasis Cubes
  Place seed in holes
    – Primed / Pelleted
    – Raw
    – Sunlight
  Place sheet of oasis cubes in a shallow tray
  Add water to pan and let water wick
– Germinate if 5 to 10 days
Young Seedlings

Seedlings are grown at a closer spacing from 1 to 4 weeks
- Dependant on temperature and light intensity
- Fertilizer / per 40 gallons of mix
  - 1 oz of 3-15-28
  - 1 oz of calcium nitrate

Growing Plants

- Are moved to the “gutters”
  - 6 to 8 inch spacing
  - 2 to 4 weeks
  - Increase fertilizer / 40 gallons of solution
    - 2, 3, 4 oz of 3-15-28
    - 2, 3, 4 oz of calcium nitrate

Larger Plants
“Water System”

“Water System”

Mature Plants

Ready for Harvest
- As much size and weight as possible
  Before bolting
  Before bitter

Marketing

Do not plant a seed until you know where the fruit is going to be sold!
- Retail
  On-Farm
  Farmer’s Market
- Wholesale

Resources and Sources

Further Resources
- G.H. Tomato
  Rick Snyder
    Mississippi State
    msucares.com/crop/s/comho/ghgreenhouse.html
- Hydroponic Lettuce
  Cornell
    www.cornell.ca
    Lettuce_Handbook/introduction.htm

Common Sources
- Local Greenhouse Suppliers
- Hydro-Gardens
  www.hydro-gardens.com
  (719) 495-2266
- Crop King
  www.cropking.com
  (330) 302-4203
Thank You!

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Questions?