### Tomato Grafting

**Historical American Views on Tomatoes**

- American’s weren’t always so fond of the fruit
- Colonials grew as an ornamental
- Associations with Nightshade (Solanum)
- Shift in perception by the 1870s
- Joseph Campbell 1897

**The Adoption of the Tomato in the United States**

- First reports of vegetable grafting occurred in Asia in the 1920’s.
  - Fusarium wilt of melon
  - Tomatoes grafted onto jimson weed as early as the 1930s to control root knot nematode
  - Alkaloid issues
  - Commercial Application by 1960s
  - Inter-specific hybrids selected for vigor and resistance to soilborne diseases.

**Vegetable Grafting Worldwide**

- 81% of Korean and 54% of Japanese vegetable production uses grafted plants

Photos courtesy of M. Peet (NCSU)
Grafting Terminology

- **Scion** – the top part of the plant
- **Rootstock** – the roots
- **Grafting Partners** – any specific rootstock/scion combination
- **Callus** – unorganized tissue mass that forms as a part of a wounding response in plants

Grafting Terminology

- **Graft Union/Graft Junction** – the point on the new plant where the scion and rootstock are joined together
- **(In)compatibility** – the inherent genetic or physiological ability/inability for two specific graft partners to form a strong, lasting graft union – may be immediate or delayed
- **Graft Failure** – death of the scion which may result from incompatibility, damage, poor technique, early sucker formation etc. often involves breakage at the graft union.

Benefits of Grafting

- **Enhanced root function**
  - Water and nutrient uptake
  - Nutrient assimilation and transport
  - Interface with soil ecosystem
- **Abiotic Stress tolerance**
  - High Tunnels
  - Salinity
  - Flooding
- **Improved Plant Vigor and Productivity**
- **Disease resistance against soilborne pathogens**
  - Alternatives to soil fumigation
  - Organic
  - phase-out of methyl bromide

Disease Management

<table>
<thead>
<tr>
<th>Rootstocks</th>
<th>Fusarium Wilt</th>
<th>Verticillium Wilt 1</th>
<th>Root-knot Nematode</th>
<th>Bacterial Wilt</th>
<th>Southern Blight</th>
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</thead>
<tbody>
<tr>
<td>Beaufort *</td>
<td>R R R R R</td>
<td>R R R R MR</td>
<td>S HR</td>
<td></td>
<td></td>
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<tr>
<td>Maxifort *</td>
<td>R R R R R</td>
<td>R R R R MR</td>
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<tr>
<td>(Unreleased) *</td>
<td>R S R R R</td>
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<td>S HR</td>
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<tr>
<td>TMZQ702 **</td>
<td>R R S R R</td>
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<td>Dai Honmei ***</td>
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<td>R R R R HR</td>
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<tr>
<td>RST-04-105 ****</td>
<td>R R R R S</td>
<td>R R R R HR</td>
<td>S HR</td>
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<tr>
<td>Big Power *****</td>
<td>R R R R S</td>
<td>R R R S S</td>
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<td>Robusta ******</td>
<td>R R S R S</td>
<td>R R R R S</td>
<td>S HR</td>
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</table>

R=Resistant, HR=Highly Resistant, MR=Moderately Resistant, S=Susceptible

* = De ‘Ruiter Seed Co.  ** = Sakata Seed Co.  *** = Asahi Seed Co.
**** = D Palmer Seed Co.  ***** = Rijk Zwaan  ****** = Bruinsma Seed Co.

www.vegetablegrafting.org

Description of Commercial Tomato Rootstocks as of February 5, 2015

- www.vegetablegrafting.org

MAXIFORT

PERFORMANCE-ENHANCING PLANTS

P. E. P.
**Assessing Rootstock Compatibility, Vigor and Yield**

- Consider a Tunnel First

**Assessing Scion Compatibility**

- Marketable Weight (lbs/plant) By Variety

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Primo Red</th>
<th>Red Deuce</th>
<th>Red Desire</th>
<th>Red Morning</th>
<th>Red Dragon</th>
<th>Red Turkey</th>
<th>Tasti Lee</th>
<th>Tunnel First</th>
<th>Open-field</th>
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**High tunnels vs open field**

- Heirloom ('Cherokee Purple') trial with little to no disease pressure from soilborne pathogens

**Gratting Effects – Yield/Season Length**

- Data indicates that the most consistent increases in yield occur early-mid season.
- In greenhouse systems, vigorous rootstocks can extend the length of the harvest season.
Summary of Benefits

- Site-specific management tool for soilborne disease.
- Disease diagnosis and rootstock selection are critical.
- Increased yield
- Vigor
- Nutrient uptake
- Abiotic stress tolerance
- Rootstock Selection
  - Vegetative vs. Generative Rootstocks
  - Heirlooms

Novelties

How Grafting Works: The Science

- Match Stem Sizes
  - Vascular Cambium gives rise to new vascular tissue

Inside the Plant

- Wounding Response to cut tissue
  - Formation of necrotic layer
  - Formation of callus tissue
- Calus tissue connects to form callus bridge
- Cells in the graft partners callus tissue recognize each other

Inside the Plant

- Vascular cambium connects across bridge and then differentiates into xylem and phloem
- Functional phloem within 3-4 days, functional xylem 6-8 days after grafting

How To Graft – The Art

Disclaimer

- No Recipe for Success
- No Substitute for Practice
- Principles
  - Transplant uniformity
  - Manage water stress
  - Sanitation
  - Re-acclimation

Photo Courtesy: M. Peet (USDA-NIFA)
There are a number of different methods for grafting vegetable crops.

**Cucurbits**
- Hole insertion
- Modified hole
- Splice/Tube
- Modified pin
- Epicotyl insertion
- Modified hole
- Tongue approach
- Splice
- Double splice

**Solanaceous**
- Spine/insertion
- Cleft
- Pin
- Modified Pin
- Splice/Tube

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### Tube Grafting Methods

**Stem Diameter Sizing**
- Planting Date
- Movement within greenhouse
- Leaf Removal Rootstock/scion

### Tube Grafting Timeline

**Tube Grafting**
- "Tube-grafting" or "Japanese top-grafting" has become the most popular for tomato.
  - Seedlings are grafted at 2-4 leaf stage.
  - High Throughput
    - A person can make ~ 1000 grafts/day
    - Grafting robots can make 700 grafts/hr.

### Tube Grafting Technique

**Stuff You Will Need**
- Sharp Hobby Knife or Razor Blade
- Scissors
- Rubbing Alcohol
- Clean Towel or Paper Towels
- Rubber Gloves
- Grafting Clips

**Surgery Prep**
- Make sure plants are not water or nutrient stressed.
- Clean indoor work area.
  - Disinfect used grafting clips.
- Wear rubber gloves
- Sterilize knife and scissors often with rubbing alcohol
  - Keep them sterile by setting on a clean towel
- Be in close proximity to healing chamber.
Grafting Clips

 Tube Grafting Technique

- Cut should be made below the cotyledon at a 60-75 degree angle. Angle uniformity between scion and rootstock is key.
- Silicon clip is slid on top of stem and scion is inserted into it.

Where to Get Clips?

Healing Chamber Management

- Your Goal Now is to Facilitate the healing process
- Healing Chamber Set-Up
  - (needs to be done prior to grafting)

Life in the Chamber

- During the healing process, the plant has to form callus tissue and reconnect vascular bundles within the stem.
- The Healing Chamber creates an “ideal” physical environment to offset the functional effects that this trauma has incurred, and give the plant time to heal itself.

Life in the Chamber

Plants begin to wilt immediately after grafting and will recover within 30-60 minutes of being moved to the chamber.
### Healing Management Timeline

<table>
<thead>
<tr>
<th>Day 1: All shade cloth on, visible fog in chamber</th>
<th>Day 7-9: If wilting has resolved, gradually remove shade cloth and increase ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 2: Reduce shade cloth by 1 layer, turn down humidity to reduce visible fog</td>
<td>Day 10-12 move out of chamber and into greenhouse</td>
</tr>
<tr>
<td>Day 3-6: Little Change, reduce humidity over these four days potential wilting, days 4-6</td>
<td><em>Ventilate Daily</em></td>
</tr>
</tbody>
</table>

### Life in the Chamber

- **Regulate humidity**
  - Cool-water vaporizers
  - "sonic"
  - Passive humidifiers
  - No warm-water vaporizers
  - No misters PLEASE
  - Overhead watering

- **Regulate Light and Temperature**
  - 50% Shade Cloth – 3-4 layers
  - Greenhouse may not be ideal location

### Wilting

- **May happen around Days 3-5**
- **Don’t Panic**
- **Don’t Crank up the Humidity**
- **Typically happens around the time the vascular system is reconnecting**

### Small Scale Chambers

#### Issues (and how to avoid them)

- Incompatibility/ Graft Failure – often indicated by scion over/undergrowth (restricts flow of water and nutrients)
- Poorly paired grafting partners – very little you can do

### Incompatibility
### Stretching
- Chamber is kept dark too long
- Remove Shade Cloth Layers
- Remove plants from chamber

### Edema
- Physiological disorder that can occur in the healing chamber.
- Relative humidity is too high.
- REMOVE plants from healing chamber if you see edema.
- Do not throw away affected plants.

### Adventitious Roots
- Very Common Problem
- Can cause graft failure.
- May reduce/eliminate benefit of disease-resistant rootstock.
- Caused by maintaining high humidity (>85%) for too long.
  - Inside AND post-chamber
- Leaf Removal

### Leaf Removal
- Scion Leaf Removal (slows down healing process a bit)
- Research with grafted tomatoes has shown that by removing leaves during grafting, success rates increase.
- Reduced water stress

### Management in the Greenhouse
- 7-10 days in the greenhouse to harden the plants post-chamber.
- Be cautious with overhead watering and any other physical disturbance.
- The clip will often fall off on its own.

### Management in the Field
- Plant so graft union is above the soil
- Pruning to eliminate rootstock suckers
Management in the Field

Sucker produced from inter-specific rootstock

Questions?