Vegetable Grafting as an IPM Tactic for Tomato Production

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Kansas State University
Tomato Grafting

- First reports of vegetable grafting occurred in Asia in the 1920’s.
  - Fusarium wilt of melon

- Popularized in Japan and Korea
  - Tunnel and Greenhouse production
Tomato Grafting

- Root function
  - Disease resistance against soilborne pathogens
  - Water and nutrient uptake
  - Nutrient assimilation and transport
  - Interface with soil ecosystem
81% of Korean and 54% of Japanese vegetable production uses grafted plants

(Lee, 2003)

Photos courtesy of M. Peet (NCSU)
Tomato Grafting in the US

- Grower adoption of grafting
  - Diverse production systems
- Home garden market
National Grafting Working Group

• SCRI Working Group (Led by NC State University)
• Developing national rootstock evaluation protocol
  – Scion issues
• Tackling national extension issues with local/regional programming
Tube Grafting

- SARE Ag-Innovations Publication
- Peer-reviewed
- Technique and Econ

(Rivard and Louws, 2011)
## Propagation Costs

### Accumulated Costs ($/plant)

<table>
<thead>
<tr>
<th>Time after sowing (weeks)</th>
<th>$0.00</th>
<th>$0.20</th>
<th>$0.40</th>
<th>$0.60</th>
<th>$0.80</th>
<th>$1.00</th>
<th>$1.20</th>
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<th>$1.60</th>
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<td>Grafted</td>
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<td>$1.88</td>
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<tr>
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<td>$1.25</td>
</tr>
</tbody>
</table>

### Production Stage Costs

- **Mark-up**
- **Cold frame**
- **18-cell tray**
- **Grafting / healing**
- **50-cell tray**
- **Germination**

- **Grafted**
  - $0.13
  - $0.67
  - $0.98

- **Non-grafted**
  - $0.44
  - $0.24

(Rivard et al., 2010)
Disease Management

Reducing soilborne pathogens and pests in crop production is important for sustainable agriculture.

Grafting herbaceous vegetable plants to manage biotic pests.


Review: Grafting fruiting vegetables to manage soilborne pathogens, foliar pathogens, arthropods and weeds

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*Department of Horticulture, Forestry and Recreation Resources, Kansas State University, Manhattan, KS 66506, USA*

*School of Plant Sciences, The University of Arizona, Tucson, AZ 85721-0036, USA*

**Abstract**

Grafting is an important integrated pest management strategy to manage soilborne pathogens and other pests of solanaceous and cucurbitaceous crops. Important diseases managed by grafting are caused by fungal pathogens such as *Verticillium*, *Fusarium*, *Pyrenochaeta* and *Monosporascus*; oomycete pathogens like *Phytophthora*; bacterial pathogens, particularly *Ralstonia*; root knot nematodes and several soil-borne virus pathogens. Rootstocks can include intraspecific selections that utilize specific major resistance genes and interspecific and intergeneric selections that exploit non-host resistance mechanisms or multigenic resistance. Rootstock selection has also been documented to impact foliar pests including pathogens, arthropods and viruses. Over-reliance on specific rootstocks in production systems has led to the emergence of new pathogens or shifts in the host specificity of the pathogen population, emphasizing the need for multi-tactic approaches to manage soilborne pathogens. One advantage and associated challenge of grafting is that rootstock selection for disease management is site specific depending on the presence, population structure and dynamics of the pathogen, as well as edaphic, environmental and anthropogenic factors. The use of grafting as an integrated pest management tool to manage biotic stress will be most successful when carried out with increasing knowledge about the biology, diversity, and population dynamics of the pathogen or other pests and when complemented with sustainable farming system practices. This review highlights major uses of grafting to manage soilborne pathogens, provides some novel information on managing foliar or other soilborne pests (insects, mites, weeds) and offers discussion on future research and applications.

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Plant Hosts

Understanding crops as pathogen hosts

- Non-host resistance
- Plant resistance
  - Multi-genic (Quantitative)
  - Single gene resistance (Qualitative)
- Plant tolerance

Susceptible  Resistant
Soil Fumigants

- Elimination of MeBr
- Chemical alternatives (Sydorovych et al., 2008)
- Grafting as an alternative to MeBr? (Kubota et al., 2008)

Pre-plant Fumigation

Photo source: Greens.org
Sclerotinia Lettuce Drop
Rootstock Evaluation

- Investigate grafting as an IPM strategy against soilborne plant pathogens.
  - *F. oxysporum f.sp. lycopersici*
  - *Meloidogyne spp.*
  - *Ralstonia solanacearum*
  - *Sclerotium rolfsii*
  - *Verticillium dahliae* (race 2)
Fusarium Wilt

- Fusarium wilt is caused by *Fusarium oxysporum*.
  - Unilateral wilting
  - Yellowing of leaves
  - Browning of xylem
Fusarium Wilt Incidence:
Alamance Co. 2006

(Rivard and Louws, 2008)
Southern Blight

- **Sclerotium rolfsii**
  - Wide host range (*Farr, 2006*)
  - Uses oxalic acid to destroy host tissue (*Punja, 1985*)

- Southern blight of tomato
  - Rapid and permanent wilt
  - Favored by hot weather
  - Host resistance reported in breeding lines (*Leeper, 1992*)
    - *L. pimpinellifolium*

- No known resistance in commercial cultivars
Southern Blight

- Combined data: 2007 and 2008 growing seasons

### Alamance County
- Non-grafted: 25-40%
- Self-grafted: 0%
- Beaufort, Maxifort: 0%

### Sampson County
- Non-grafted: 50-80%
- Self-grafted: 1-5%
- Telone II, Big Power, Beaufort, Maxifort: A

AUDPC values for southern blight

- Non-grafted: C
- Self-grafted: BC
- Telone II, Big Power, Beaufort, Maxifort: A

**Legend:**
- Red = Non- and self-grafted
- Blue = Big Power, Beaufort, Maxifort

- ‘Big Power’, ‘Maxifort’ and ‘Beaufort’ displayed excellent resistance to southern blight (*S. rolfsii*).
- Quantitative nature of resistance
- Possible role of calcium (*Punj[a, 1985; Mohr, 1959; Leonardi, 2006*)

*(Rivard et. al., 2010)*
Root-knot Nematodes

- **Meloidogyne spp.**
  - Obligate biotrophs
  - Wide host range
  - Giant cell formation

- Southern RKN
  - *M. incognita* (race 1)
  - Root galls, stunting, poor vigor and yield (*Overman, 1991*).
  - **Mi** gene (*Gilbert, 1956*)
    - Causes HR and is unstable >28° C (*Dropkin, 1969*).

- **Mi** efficacy in inter-specific tomato Rootstock
  - **Mi** is quantitatively effective in against *M. javanica* in several rootstocks (*Cortada et al., 2008*).
  - **Mi 1.2** verified by REX-1 and Mi23 markers
  - **Mi** confers “tolerance” in ‘Beaufort’ (*Lopez-Perez et al., 2006*).
Root-knot Nematodes

- Combined data: 2007 and 2008 growing seasons

- Chart A: Days after planting vs. RKN galling index for Non-grafted, Self-grafted, Telone II, Big Power, Beaufort, and Maxifort.

- Chart B: AUDPC values for RKN galling for Non-grafted, Self-grafted, Telone II, Big Power, Beaufort, and Maxifort.

- Key:
  - Red = Non-, self-grafted
  - Orange = Big Power
  - Blue = Beaufort, Maxifort

(Rivard et al., 2010)
## Root-knot Nematodes

- Combined data: 2007 and 2008 growing seasons

### Table 1.3. Root-knot nematode soil population at Sampson County

<table>
<thead>
<tr>
<th></th>
<th>First harvest</th>
<th>Final harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-grafted</strong></td>
<td>8357 d</td>
<td>1964 b</td>
</tr>
<tr>
<td><strong>Self-grafted</strong></td>
<td>8751 d</td>
<td>1228 b</td>
</tr>
<tr>
<td><strong>Telone II</strong></td>
<td>379 b</td>
<td>1260 b</td>
</tr>
<tr>
<td><strong>Big Power</strong></td>
<td>77 a</td>
<td>40 a</td>
</tr>
<tr>
<td><strong>Beaufort</strong></td>
<td>2680 c</td>
<td>2542 b</td>
</tr>
<tr>
<td><strong>Maxifort</strong></td>
<td>3091 c</td>
<td>1251 b</td>
</tr>
</tbody>
</table>

- Red = Non-, self-grafted
- Orange = Big Power
- Black = Fumigated (Telone II)
- Blue = Beaufort, Maxifort

(Rivard et. al., 2010)
Verticillium Wilt

- **Verticillium dahliae**
  - Loss of vigor
  - Wilting and leaf necrosis
  - Favored by cool wet weather
  - Race 2 prevalent in WNC (Bender & Shoemaker, 1984)
  - Reliance on fumigation
Verticillium Wilt

Lancaster County - 2009

Non-grafted Maxifort

Marketable fruit yield (tons/acre)

<table>
<thead>
<tr>
<th></th>
<th>Non-Fumigated</th>
<th>Fumigated</th>
<th>Non-Fumigated</th>
<th>Fumigated</th>
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<tbody>
<tr>
<td>Non-grafted</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Maxifort</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

LSD $P = 0.05$
### Economic Returns

#### Net returns of grafting ($/acre) : 2008

<table>
<thead>
<tr>
<th>Spacing</th>
<th>Non-grafted*</th>
<th>Maxifort*</th>
<th>(Max-Std)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18&quot;</td>
<td>$44,525</td>
<td>$47,366</td>
<td>$2,841</td>
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<tr>
<td>24&quot;</td>
<td>$47,827</td>
<td></td>
<td>$3,302</td>
</tr>
<tr>
<td>36&quot;</td>
<td>$45,533</td>
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<td>$1008</td>
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</table>

#### Net returns of grafting ($/acre) : 2009

<table>
<thead>
<tr>
<th>Fumigated</th>
<th>Non-grafted*</th>
<th>Maxifort*</th>
<th>(Max-Std)</th>
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<tbody>
<tr>
<td></td>
<td>$47,739</td>
<td>$60,699</td>
<td>$12,960</td>
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<tr>
<td>Non-fumigated</td>
<td>$57,677</td>
<td>$9,938</td>
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</tbody>
</table>

*Values = Gross revenue – harvest costs – transplant costs
Selling price = $0.66 per lbs
## Disease Management

<table>
<thead>
<tr>
<th>Rootstocks</th>
<th>TMV</th>
<th>Corky Root</th>
<th>Fusarium Wilt</th>
<th>Verticillium Wilt</th>
<th>Root-knot Nematode</th>
<th>Bacterial Wilt</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Race 1</td>
<td>Race 2</td>
<td></td>
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</tr>
<tr>
<td>Beaufort</td>
<td>* R</td>
<td>R</td>
<td>R  R  R  R</td>
<td>R</td>
<td>MR</td>
<td>S</td>
</tr>
<tr>
<td>Maxifort</td>
<td>* R</td>
<td>R</td>
<td>R  R  R  R</td>
<td>R</td>
<td>MR</td>
<td>S</td>
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<tr>
<td>(Unreleased)</td>
<td>* R</td>
<td>S</td>
<td>R  R  R  R</td>
<td>R</td>
<td>R</td>
<td>HR</td>
</tr>
<tr>
<td>TMZQ702</td>
<td>** R</td>
<td>S</td>
<td>R  R  R  R</td>
<td>R</td>
<td>R</td>
<td>MR</td>
</tr>
<tr>
<td>Dai Honmei</td>
<td>*** R</td>
<td>R</td>
<td>R  R  S  R</td>
<td>R</td>
<td>R</td>
<td>HR</td>
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<tr>
<td>RST-04-105</td>
<td>**** R</td>
<td>R</td>
<td>R  R  R  R</td>
<td>R</td>
<td>R</td>
<td>HR</td>
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<tr>
<td>Big Power</td>
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<td>R  R  R  R</td>
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<td>S</td>
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<tr>
<td>Robusta</td>
<td>****** R</td>
<td>R</td>
<td>S  R  R  R</td>
<td>R</td>
<td>S</td>
<td>S</td>
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<td>R</td>
<td>MR (R)</td>
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<tr>
<td>Maxifort</td>
<td>*</td>
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<td>S (R)</td>
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<td>R</td>
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2006 SR-SARE R&E Grant

- Compare production dynamics of tunnel vs field production.
  - Environment
  - Disease
  - Productivity
  - Economics

- Optimize cultural practices for high tunnels.
  - Nutrient / Fertility
  - Planting Date

- Investigate the role of grafting for open-field and tunnel production.
  - Beaufort
  - Maxifort
  - Nutrient uptake efficiency

‘Cherokee Purple’
The main effect of grafting was significant in both years, across systems, and with both data sets (100 DAP vs “systems”). System*grafting = NS
The main effect of grafting was significant in both years, across systems, and with both data sets (100 DAP vs “systems”). System*grafting = NS
• Bi-weekly harvest data was collected into five bins.
  – Last bin was the final (terminal) harvest
  – Previous four were equivalent divisions of the harvest season
• Each interval = 3 weeks in the tunnel or 2 weeks in the open-field
• Grafting tomato with interspecific rootstock is an effective disease management tool.
  – Single gene resistance
    • Fusarium Wilt
    • Root-knot Nematodes
    • “Instability” of Mi gene
  – Quantitative resistance
    • Bacterial Wilt (*R. solanacearum*)
    • Southern Stem Blight (*Sclerotium rolfsii*)
  – Disease tolerance
    • Verticillium Wilt (*V. dahliae* (r 2))

• Disease diagnosis and rootstock selection are critical.
  – Role of extension
Conclusions

- Use of rootstocks may increase yield through added vigor and nutrient uptake.
  - Fertility recommendations
  - Rootstock-specific
  - Rootstock/Scion interactions

- Cultural management may reduce economic constraints.
  - Planting density
  - Pruning/training
  - Fertility
Tomato Grafting Research at KSU

- Transplant Production
- Rootstock Evaluation
- Cultural management of grafted plants
- Development of high tunnel systems

2011 On-farm grafting trial

Research → Extension
Tomato Grafting Research at KSU

Sarah Masterson, M.S.
Student
Committee members:
Rhonda Janke
Megan Kennelly

THE CERES TRUST

NORTH CENTRAL SARE
Sustainable Agriculture Research & Education
On-Farm Research

• Benefits of On-farm Research
  - Diverse production systems
  - Evaluation in the “real world”
  - Early grower adoption
  - Grower engagement
Olathe Trial 2011 & 2012 Yield

- Nongrafted
- Maxifort (std)
- Maxifort (top)
- Trooper (std)
- Trooper (top)

Yield comparison for different treatments across two years, 2011 and 2012. P=0.05 indicates statistical significance.
Gieringer’s Orchard  2011 & 2012 Trial Yield

P=0.05
Summary

- Works well, but may not be for everyone
  - Production system
  - Economics (market/selling price)
  - Scion variety

- Local rootstock needs
  - Vigor
  - Verticillium wilt, RKN
  - Soil salinity

- Grafting technique can be difficult for some
  - Greenhouse facilities, etc.