CIOA
The Carrot Improvement for Organic Agriculture Project
Better Carrots for Organic Growers and U.S. Consumers

USDA-NIFA OREI award #2011-51300-30903

Project collaborators
Phil Simon (PI), USDA ARS, University of Wisconsin Madison
Micaela Colley, Laurie McKenzie, Jared Zystro, Cathleen McCluskey, Organic Seed Alliance
Lori Hoagland, Purdue
Phil Roberts, University of California, Riverside
Erin Silva and Jed Colquhoun, University of Wisconsin Madison
Joe Nunez, University of California, Kern County Extension
Tim Waters and Lindsey du Toit, Washington State University
Today’s Webinar

- **Project introduction and overview** - Phil Simon and Micaela Colley
- **Breeding for nematode resistance** - Phil Roberts
- **Genotype x soil microbial interaction** - Lori Hoagland
- **Preliminary results** - Jared Zystro
- **CIOA website, outreach and related resources** - Cathleen McCluskey
- **Question and Answer**

Who needs better carrots?

14.3% of the U.S. carrot crop is in organic systems

**Organic growers & Consumers**

- Orange & novel colors
- Disease & pest resistance
  - Nematodes
  - Leaf blights
- Weed competitive
  - Early vigor
  - Canopy size

**CIOA carrot**

- Colorful – convenient - crunchy
- Culinary Quality
  - Sweet
  - Not harsh (turpentiney, “bitter”)
  - Succulent
- Nutritional Quality
CIOA: The Carrot Improvement for Organic Agriculture Project

- Information for growers and consumers – variety trials, production information
- Related research activities – nematode resistance, soil microbial analysis, production systems research (organic and conventional paired trials)
- Germplasm development – breeding for organic systems

Field trials – CA, IN, WA, WI – Four Years
Organic and conventional paired management trials
36 entries – 16 cultivars, 20 breeding stocks

- WI: Erin Silva summer crop
  - Center for Integrated Agricultural Systems and Department of Plant Pathology, University of Wisconsin, Madison, WI
- IN: Lori Hoagland summer crop
  - Department of Horticulture & Landscape Architecture, Purdue University, West Lafayette, IN
- WA: Tim Waters summer crop
  - Area Extension, Commercial Vegetables, Washington State University, Pasco, WA
- CA: Joe Nunez winter crop
  - University of California Cooperative Extension, Farm and Home, Bakersfield CA
Evaluation traits:

- Root yield
- Appearance
- Flavor – sweetness, harsh flavor
- Nutritional value – carotenoids, anthocyanins, nitrates
- Foliar disease resistance
- Root-knot nematode resistance
- Soil quality and carrot growth
- Top size - weed competition
Carrot cultivars included in the CIOA project

- Bolero
- Brasilia
- Creampak*
- Hilmar
- Karotan
- Napoli
- Nelson
- Purple Haze*
- Red Core Chantenay
- Rumba
- Spring Market
- SugarSnax
- Sun 255
- Upper Cut
- Western Red
- Yellow Stone*

*Not included year 1

Carrots in the CIOA project – cultivars
Red Core Chantenay  Bolero  Western Red
Carrots in the CIOA project – cultivars

Brasilia  Sun 255  SugarSnax

Carrots in the CIOA project – experimentals

R6637  Y8519  Nb8524
Carrots in the CIOA project – experimentals

P1128  P6306  P0191

Research related to CIOA traits of interest to growers

- Root yield
- Appearance
- Flavor
- Nutritional value
- **Foliar disease resistance**
- **Root-knot nematode resistance**
- **Soil quality and carrot growth**
- Top size - weed competition
Evaluation of foliar diseases

- Lindsey du Toit
  - Washington State University, Mount Vernon, WA
- Foliar disease diagnosis for samples from CA, IN, WA, WI
  - Alternaria and Cercospora leaf blights, Xanthomonas bacterial blight, and powdery mildew observed

- Pamela Moreno – Univ. Wisc. Grad student
  - Alternaria leaf blight resistance from new genetic sources

Root-knot Nematode Resistance Breeding in Carrots

Phil Roberts
Department of Nematology
University of California - Riverside
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Root-Knot Nematode Reproduction and Root Galling

Sources of resistance to root-knot nematodes
(Meloidgyne spp.)

Brasilia-1252 (Mj-1, dominant, + Mi genes)
R to M. javanica and M. incognita
(Br-1252 x USDA inbreds)

Non-Brasilia:
Homs – High M. incognita resistance
M. javancia resistance

Ping Ding; Scarlet Fancy x Favourite; Western Red, Scarlet Nantes; Gold King Cross

R x R: Br 1091 x Homs; SFF x Homs
Root-knot nematodes (*Meloidogyne* spp.)

- Challenge of variability for response to resistance
  - Variation between main species
  - Variation within species

- 45 isolates
- *M. incognita* -- 25
- *M. javanica* -- 7
- *M. arenaria* -- 2
- *M. hapla* -- 11

### Greenhouse resistance screening
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**Greenhouse resistance screening**

Field screens to assess resistance

Scale

0 1 2 3 4 5 6 7 8 9 10
South Coast REC Field Day & Trial Assays
November 2014

Direct involvement of seed companies

Screen USDA & seed industry breeding lines
UC Field Site Evaluations for Root-Knot Nematode Resistance in 2014

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>Root-knot isolate</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Coast Res. Irvine (Orange Co.) &amp; Extn. Center (SCREC)</td>
<td><em>M. incognita</em></td>
<td></td>
</tr>
<tr>
<td>South Coast Res. Irvine (Orange Co.) &amp; Extn. Center (SCREC)</td>
<td><em>M. javanica</em></td>
<td></td>
</tr>
</tbody>
</table>

1,600 plots; roots selected
-- 61% (inbreds) - 70% (advanced) of *M. incognita* plots with good resistance (scores < 2)
-- 7 new inbreds released

South Coast REC Field Day & Trial Assays November 2014
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Kearney REC Field Day & Trial Assays
September 2013 - Parlier

Resistant lines with good agronomic traits

3-way hybrid

Advanced breeding line
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**M. incognita -- 25 isolates**

Range 0.6 – 3.0 (4)

<table>
<thead>
<tr>
<th>Resistance sources</th>
<th>Gall index</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCR 4</td>
<td>6.6</td>
</tr>
<tr>
<td>UCR 40</td>
<td>2.3</td>
</tr>
<tr>
<td>4001</td>
<td>2.2</td>
</tr>
<tr>
<td>Sem</td>
<td>3.0</td>
</tr>
<tr>
<td>F4</td>
<td>1.9</td>
</tr>
<tr>
<td>H1</td>
<td>4.1</td>
</tr>
<tr>
<td>H2</td>
<td>3.7</td>
</tr>
<tr>
<td>H x B</td>
<td>1.8</td>
</tr>
<tr>
<td>SFF</td>
<td>4.0</td>
</tr>
<tr>
<td>WR</td>
<td>5.8</td>
</tr>
<tr>
<td>PD</td>
<td>2.9</td>
</tr>
<tr>
<td>I 58</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Summary Points

- Carrots highly susceptible to root-knot nematodes
- Excellent sources of resistance available
  - Broadly affective
  - Gaining knowledge of genomic organization for developing molecular markers
  - Resistant varieties available in near future
- Long-term investment – organic & conventional
- Team effort essential
Genotype x soil microbial interaction

Lori Hoagland
Assistant Professor
Purdue University

The root microbiome

• **Definition**: The dynamic community of microbes associated with the plant root

• Microbes greatly outnumber plant cells – 2\textsuperscript{nd} genome

• Implications for plants
  - Nutrient acquisition
  - Biotic and abiotic stress
  - Physiological processes (ex. flowering)
  - Fruit quality
Factors affecting microbial community assembly

- Colonization is the result of carefully orchestrated processes ex. Rhizobia and Mycorrhiza
- Plants
  - Species
  - Genotype
- Resident soil microbial community structure
  - Soil type
  - Land-use practices

Learning more about plant-microbial relationships

- Carrot - ideal model crop
- Crop Systems Trial (G×ExM)
  - 36 genotypes (G)
  - 4 environments (E)
  - 2 management systems (M)
- Approach:
  1) characterize soil quality in all environments and systems
  2) identify the composition and function in nine genotypes in Indiana crop systems trial
Inside the carrot root microbiome

- Pathogen suppression
- Endophytes
  - more host specific than rhizosphere microbes
  - genotype specific
  - conserved across environments and physiological stages
  - most thought to be mutualistic
  - most viable but not culturable – *induced under stress*

Preliminary results – 2014

- Soil microbial biomass and activity greater in organic
- Soil microbial community structure differed between systems
- No difference in carrot yield
- Foliar pathogen infection greater in conventional system in two genotypes
### Carrot Improvement For Organic Agriculture

#### Preliminary results - Culturable endophyte diversity

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fungi</td>
<td>Uncultured Cladosporium</td>
<td>-</td>
</tr>
<tr>
<td>Fungi</td>
<td>Cladosporum cladospores</td>
<td>Cladosporum cladospores</td>
</tr>
<tr>
<td>Fungi</td>
<td>-</td>
<td>Uncultured Ascomycota/Epicoccum spp.</td>
</tr>
<tr>
<td>Fungi</td>
<td>-</td>
<td>Uncultured Phyllocladaceae/Closterotrichum</td>
</tr>
<tr>
<td>Fungi</td>
<td>-</td>
<td>Colletotrichum cocodes</td>
</tr>
<tr>
<td>Fungi</td>
<td>-</td>
<td>Uncultured Ergyodontium spp.</td>
</tr>
<tr>
<td>Bacteria</td>
<td>-</td>
<td>Uncultured Stenotrophomonas spp.</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Stenotrophomonas maltophilia</td>
<td>Stenotrophomonas maltophilia</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Uncultured Xanthomonas spp.</td>
<td>Uncultured Xanthomonas spp.</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Xanthomonas oryzae</td>
<td>Xanthomonas oryzae</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Xanthomonas campestris</td>
<td>-</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Bacillus megabacterium</td>
<td>-</td>
</tr>
<tr>
<td>Bacteria</td>
<td>-</td>
<td>Paenibacillus spp.</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Rhizobium etli</td>
<td>-</td>
</tr>
<tr>
<td>Bacteria</td>
<td>-</td>
<td>Rhizobium giardii</td>
</tr>
<tr>
<td>Bacteria</td>
<td>-</td>
<td>Methylbacterium spp.</td>
</tr>
<tr>
<td>Bacteria</td>
<td>-</td>
<td>Uncultured Pseudomonas spp. (2 – distinct isolates)</td>
</tr>
<tr>
<td>Bacteria</td>
<td>-</td>
<td>Pseudomonas flourescens (3 – distinct isolates)</td>
</tr>
<tr>
<td>Bacteria</td>
<td>-</td>
<td>Pseudomonas oleovorans</td>
</tr>
<tr>
<td>Bacteria</td>
<td>-</td>
<td>Pseudomonas brassiacernum</td>
</tr>
</tbody>
</table>

#### Preliminary results - Culturable endophyte abundance

**Count on R2A media for oligotrophic bacteria**

<table>
<thead>
<tr>
<th>Entry</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp 0191 - Asia</td>
<td>3 X 10³</td>
<td>2.2 X 10⁸</td>
</tr>
<tr>
<td>Exp 6306 - Asia</td>
<td>2.75 X 10⁴</td>
<td>8.0 X 10⁶</td>
</tr>
<tr>
<td>Exp 0252 - Syria</td>
<td>1.0 X 10²</td>
<td>too many to count</td>
</tr>
<tr>
<td>Exp 8519 - Turkey</td>
<td>2.1 X 10⁴</td>
<td>2.0 X 10⁶</td>
</tr>
<tr>
<td>Exp 3999 – Brazil/Europe</td>
<td>8.12 X 10⁷</td>
<td>2.0 X 10⁸</td>
</tr>
<tr>
<td>Karotan - Europe</td>
<td>4.3 X 10³</td>
<td>4.5 X 10⁸</td>
</tr>
<tr>
<td>Scarlet Fancy X Favorite – United States</td>
<td>1.9 X 10⁵</td>
<td>4.5 X 10⁸</td>
</tr>
<tr>
<td>Brasilia - Brazil</td>
<td>1.8 X 10⁵</td>
<td>2.0 X 10⁸</td>
</tr>
<tr>
<td>Red Core Chantenay - Europe</td>
<td>1.3 X 10³</td>
<td>6.5X 10⁸</td>
</tr>
</tbody>
</table>

- Count on R2A media for oligotrophic bacteria
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On-going experiments

• What can the culturable isolates do?
  - phytohormone production?
  - antibiotic production?
  - nutrient acquisition?

• What else is living inside these roots?
  - culture-independent community profiling

• Can they help the plant withstand soil-borne and foliar diseases?

• How does the plant and endophyte communities respond in the presence of a pathogen?

Conclusions and future directions

• Plant-microbial relationships are specific and have significant implications for crop productivity

• Microbes are abundant in carrot roots

• Identify superior microbial isolates for seed inoculants

• Integrate selection for beneficial plant-microbial relationships in breeding programs

You are what you eat
Preliminary results from 2011 and 2012 CIOA field trials

Jared Zystro
Organic Seed Alliance

Methods

• Trials grown in 2011 and 2012
• California, Washington, Wisconsin, and Indiana
• Paired organic and conventional systems
• 36 entries
• Randomized complete block design (RCBD) with three replications.
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Traits

• Plant width
• Plant height
• Root weight
• Top weight
• Harshness
• Sweetness

Analysis

• Analysis of variance (ANOVA)
• Means, based on Best Linear Unbiased Estimators (BLUEs)
• Spearman rank correlations
• Kang’s stability statistic
Results

• Differences between entries for top height and width, top mass, root weight, sweetness, and harshness.

• Entry ranks not always consistent between different years or locations.

• Entry ranks generally consistent between paired organic and conventional systems in same year and location.
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Results

• Some entries performed more consistently across environments than others.
CIOA Online Resources

Website  Searchable Gallery  Organic Variety Trial Database

Cathleen McCluskey, Organic Seed Alliance, cathleen@seedalliance.org
Carrot Improvement for Organic Agriculture (CIDA) is a long-term breeding project that addresses the critical needs of organic carrot farmers by developing orange and novel colored carrots with improved disease and nematode resistance, improved weed competitiveness, and improved nutritional value and flavor. This four-year project will also compare the relative performance of breeding... Read more

Resources

Resources for Organic Carrot Breeding and Seed Production

Online Tutorial: Carrot Seed Production
Video: Carrot Seed Production
Power Point: Carrot Seed Production
Publication: Principles and Practices of Organic Carrot Seed Production in the Pacific Northwest
Webinar Recording: Breeding Carrots as part of the Northern Organic Vegetable Improvement Collaborative (NOVIC)
Webinar Recording: Breeding for Positive Microbial Interactions
Webinar Recording: Breeding for Nutrition
Online Article: Plant Pigments for Color and Nutrition
Trial Results: Carrot Trial Results from Dr. Phil Simon Breeding Projects (1998 - 2011)
Power Point: Pacific Northwest Carrot Diseases

Online Tutorial: Carrot Seed Production This is one of five basic organic seed production on-line tutorials available through extension. This course was created by Organic Seed Alliance, through a grant from Western SARE. It is based on materials from organic seed intensive workshops held as part of the 2011 Organicology conference.

Video: Carrot Seed Production CIDA collaborator, Dr. John Navazio of Organic Seed Alliance and Washington State University, presents on the how-to’s of Carrot Seed Production at the 2011 Organicology Conference in Portland, Oregon.

Power Point: Carrot Seed Production CIDA collaborator, Dr. John Navazio of Organic Seed Alliance and Washington State University’s, Power Point presentation from the above video presentation on Carrot Seed Production.

Publication: Principles and Practices of Organic Carrot Seed Production in the Pacific Northwest Organic Seed Alliance’s 17 page manual on organic carrot seed production. This, like all other Organic Seed Alliance publications, is available for free download from their website (follow link provided). It’s a great manual to print off and take into the greenhouse or field.

Webinar Recording: Breeding Carrots as part of the Northern Organic Vegetable Improvement Collaborative (NOVIC) CIDA collaborator, Dr. John Navazio of Organic Seed Alliance and Washington State University, presents on carrot breeding principles specifically within the NOVIC project. This is a recording of a live webinar broadcast by Organic Seed Alliance and eorganic from the 6th Organic Seed Growers Conference.
Carrot Improvement for Organic Agriculture (CIOA) is a long-term breeding project that addresses the critical needs of organic carrot farmers by developing orange and novel colored carrots with improved disease and nematode resistance, improved weed competitiveness, and improved nutritional value and flavor. This four-year project will also compare the relative performance of breeding... Read more

News

Carrot Country -- Winter 2012 National Project to Improve Organic Production Systems Launched

Events

Carrot Improvement for Organic Agriculture Webinar Join eOrganic for this free webinar to learn about the Carrot Improvement for Organic Agriculture project on March 24, 2015.

Searchable Gallery

http://carrots.eorganic.info/

Specialty Carrots

A gallery of carrots types by the Carrot Improvement for Organic Agriculture Project.

Color  Disease Resistance  Shape  Flavor  Length  Origin  Top Size  Commercially available

CIOA 30  Botero (Wilmerd)  CIOA 23  Brasilia  CIOA 27  Creampak (Nurhems)  CIOA 11  Exp No 9999
Carrot Improvement For Organic Agriculture

Filtered Searches

Filtered Search Results
PING DING

Origin: China
Length: Medium
Shape: Conical
Top Size: Medium
Flavor: Below Average
Color: Purple Orange/Purple Yellow
Commercially available: No

Organic Variety Trial Database

Carrot Improvement for Organic Agriculture

Carrot Variety Database

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Searchable Gallery

Organic Variety Trial Database
Organic Variety Trial Database
http://varietytrials.eorganic.info/

Filtered Searches
Questions and Feedback

Cathleen McCluskey
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(360) 472-0247