# Identifying phenotypes, markers, and genes in carrot germplasm to deliver improved carrots to growers and consumers

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# Carrot Germplasm

- ~1100 Plant Introductions in USDA collection, Ames, IA
- The ultimate source of natural genetic variation
- ~650 cultivated
  - Old open-pollinated carrots
  - Foreign carrots “land races”
- ~450 wild carrots

- Inbreds in breeding programs

# Top 19 Traits for Improvement

## 2014 Survey; Jan. 9, 2015 stakeholder meeting

| | | |
|---|---|---|
| 1 | Cavity spot | **Pests and Disease** |
| 2 | Nematodes | |
| 3 | *Alternaria dauci* leaf blight | |
| 4 | *Xanthomonas* blight | |
| 5 | *Rhizoctonia* | |
| 6 | Black crown | |
| 7 | Powdery mildew | |
| 1 | Sweetness, flavor | **Quality and Nutrition** |
| 2 | Carotenoids | |
| 3 | Anthocyanins | |
| 4 | Cracking | |
| 5 | Texture | |
| 6 | Sugars and solids | |
| 1 | Stand establishment | **Production Characteristics and Abiotic Stress** |
| 2 | Bolting tolerance | |
| 3 | Drought stress resistance | |
| 4 | Heat stress resistance | |
| 5 | Forking | |
| 6 | Petiole attachment | |

# Traits in the Carrot Proposal for Improvement

2014 Survey; Jan. 9, 2015 stakeholder meeting

| | | |
|---|---|---|
| **1** | Cavity spot | **Pests and Disease** |
| **2** | Nematodes | |
| **3** | *Alternaria dauci* leaf blight | |
| **1** | Sweetness, flavor | **Quality and Nutrition** |
| **2** | Carotenoids | |
| **3** | Anthocyanins | |
| **1** | Stand establishment | **Production Characteristics and Abiotic Stress** |
| **2** | Bolting tolerance | |
| **3** | Drought/heat stress resistance | |

# A high-quality carrot genome assembly provides new insights into carotenoid accumulation and asterid genome evolution

Massimo Iorizzo1,12, Shelby Ellison1, Douglas Senalik1,2, Peng Zeng3, Pimchanok Satapoomin1, Jiaying Huang3, Megan Bowman4, Marina Iovene5, Walter Sanseverino6, Pablo Cavagnaro7,8, Mehtap Yildiz9, Alicja Macko-Podgórni10, Emilia Moranska10, Ewa Grzebelus10, Dariusz Grzebelus10, Hamid Ashrafi11,12, Zhijun Zheng3, Shifeng Cheng3, David Spooner1,2, Allen Van Deynze11 & Philipp Simon1,2

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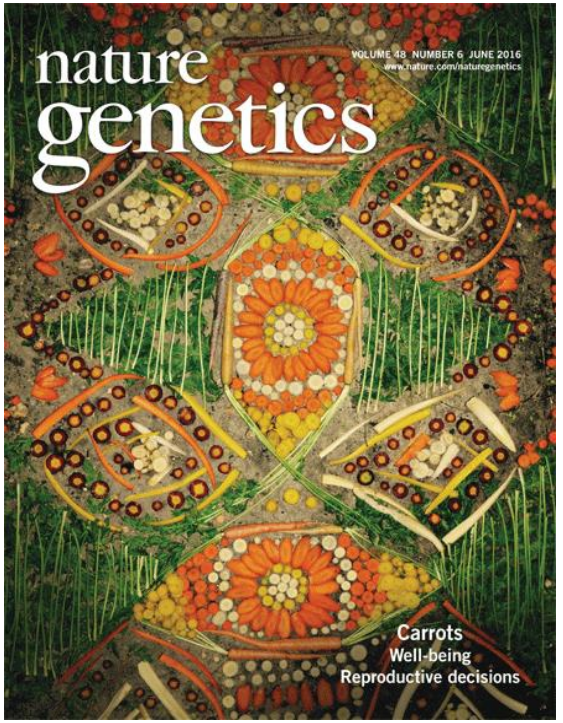
**WE PUBLISHED THE CARROT GENOME IN 2016**



# Identifying phenotypes, markers, and genes in carrot germplasm to deliver improved carrots to growers and consumers

## USDA-NIFA-Specialty Crop Research Initiative

## Standard Research and Extension Project

# Project Objectives

- Phenotype diverse carrot germplasm and breeding stocks to discover and describe previously uncharacterized variation for traits important for: improving carrot disease and pest resistance, reliable crop production and tolerance to environmental stress, enhanced consumer quality and superior color and nutritional value
- Develop an expanded carrot genomic database for breeders to catalogue genomic and phenotypic variation and track genes underlying important traits
- Carrot germplasm utilization and evaluation

  Initiate development and evaluation of breeding pools from diverse germplasm and breeding stocks

  Consumer evaluation of carrot flavor

  Bioefficacy evaluation of carrot nutritional quality

- Evaluate the economic impacts of new carrot traits on grower practices and costs, and consumer decisions

# Project Activities

- 18 project investigators and scientists from 10 U.S. institutions
- Research and Outreach components for each project objective
- 5 year project
  - Most field phenotyping activities in years 1-4
  - Breeding pool development 3-5
- Advisory meetings
- Database discussions at Plant and Animal Genome meetings in January, 2020

## Fall 2014 – 113 Carrot industry and researchers were surveyed, 35% response

***For each of the first 11 trait categories below, the following questions were asked:***

| Does this trait contribute to improving carrot productivity and/or value? Check all that apply. | | How important is this trait in a carrot breeding program? | Is additional research needed for this trait? |
|---|---|---|---|
| Improves Fresh Market Value | Improves Processing Value | Not at all / Slightly/ Somewhat/ Very /Extremely | Yes No |

**Which of the carrot traits listed below about [list of 1-11 below] could contribute to improving the crop to meet your current and future needs? Please answer the above questions for each of these traits.**

1-Appearance of the storage root
Overall uniformity
Root shape
Length
Diameter
Core or xylem diameter
Shoulder shape
Taper
Surface smoothness
Lateral roots prominence
Forking tendency
Fibrous root prominence
Shoulder color
Root surface color
Cortex or phloem color
Internal color uniformity
Zoning or vascular cambium color
Core or xylem color
Other traits: Please specify
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2-Quality of the storage root
Sweetness or sweet flavor
Harshness or turpentiney, bitter flavor
Texture
Cracking tendency or brittleness
Other traits: Please specify
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3-Composition of the storage root
Sugars or soluble solids
Carotenoids or orange, red, yellow pigments
Anthocyanins or purple pigments
Fiber
Other traits: Please specify
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4-Characteristics of the seed
Length or width
Weight
Other traits: Please specify
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5-Seedling and vegetative plant growth
Seed germination percent
Germination speed or uniformity
Seedling growth rate
Top growth rate
Root growth rate
Other traits: Please specify
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6-Characteristics of the top or vegetative (non-flowering) plant
Top diameter
Top height
Top erectness
Petiole attachment strength
Bolting tolerance or ease of floral initiation
Other traits: Please specify
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7-Characteristics of the flowering plant during seed production
Number or size of umbels
Duration of flowering
Pollen fertility
Female fertility
CMS stability
CMS restorers
Other traits: Please specify

| | |
|---|---|
| 8-Field diseases and pests<br>Seedling damping-off or dieback<br>Alternaria leaf blight (A. dauci)<br>Black crown or rot (A. radicina)<br>Cercospora leaf blight<br>Cavity spot (Pythium)<br>Xanthomonas bacterial blight<br>Aster yellows<br>Motley dwarf or other mycoplasma<br>Southern root knot nematodes<br>Northern root knot nematodes<br>Other nematodes<br>Carrot fly<br>Other field diseases and pests: Please specify<br>9- Postharvest diseases and pests<br>Cavity spot (Pythium)<br>Rhizoctonia - crown or canker rot<br>Sclerotinia soft rot<br>Alternaria leaf blight (A. dauci)<br>Black crown or rot (A. radicina)<br>Other postharvest diseases and pests: Please specify- | 10-Seed crop diseases and pests<br>Alternaria leaf blight (A. dauci)<br>Xanthomonas bacterial blight<br>Powdery mildew (Erysiphe)<br>Other seed crop diseases and pests: Please specify<br><br>11-Abiotic stress<br>Heat stress<br>Cold stress<br>Drought stress<br>Standing water stress<br>Salt stress<br>Over winter seed to seed stand<br>Other abiotic stress: Please specify |

***Participants were also asked the following open-ended questions:***

12-Are there any **additional traits** that could contribute to improving the crops to meet your current and future needs? (If yes, please describe)

13-Should additional research on **nutritional quality** be undertaken to inform future carrot improvement? (If yes, please describe)

14-Should additional research on **consumer perceptions** be undertaken to inform future carrot improvement? (If yes, please describe)

15-Should additional research on **carrot markets** be undertaken to inform future carrot improvement? (If yes, please describe)

16-Should additional research on **health properties** be undertaken to inform future carrot improvement? (If yes, please describe)

17-Should additional research on **carrot crop production and management (e.g. soil quality and microbiota, organic and conventional, intercropping)** be undertaken to inform future carrot improvement? (If yes, please describe)

18-Should additional research on **development of carrot genomic tools** be undertaken to inform future carrot improvement? (If yes, please describe)

19-Should additional research in **other areas** be undertaken to inform future carrot improvement? (If yes, please describe)