40th International Carrot Conference

August 29-30, 2022

Mount Vernon, Washington, USA

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Mount Vernon, Washington, U.S.A.
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Monday, August 29 Agricultural Research & Technology Building, WSU Mount Vernon Northwestern Washington Research & Extension Center (NWREC)

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7:30 am	**Registration desk open, and morning refreshments**	
8:15 am	**Welcome and general announcements** – Lindsey du Toit, Vegetable Seed Pathologist and Chair of the Organizing Committee, WSU Mount Vernon NWREC	
8:25 am	**Welcome to the WSU Mount Vernon NWREC** – Carol Miles, Director, WSU Mount Vernon NWREC	
8:40 am	**Agriculture in Northwestern Washington** – Brandon Roozen, Executive Director, Western Washington Agricultural Association	
9:00 am	**Keynote Presentation: Experiences, learnings, and observations from 40+ years of carrot breeding** – Roger Freeman, Senior Breeder, Nunhems USA, Inc.	5
9:30 am	**Break, morning refreshments sponsored by BASF Nunhems**	
10:00 am	**Creating connections, igniting inspiration and imagination, and having fun through Participatory Plant Breeding with carrots.** Laurie McKenzie and Micaela Colley	6
10:20 am	**Results of the carrot SCRI project: New phenotypes, markers, and genes in carrot germplasm to deliver improved carrots to growers and consumers.** Phil Simon, David Spooner, Julie Dawson, Edgar Spalding, Sherry Tanumihardjo, Massimo Iorizzo, Phil Roberts, Allen Van Deynze, Theresa Hill, Daniel Sumner, Jas Sidhu, Lindsey du Toit, Timothy Waters, Micaela Colley, and Laurie McKenzie	7
10:40 am	**Comparison of genotypic and phenotypic selection of breeding parents in a carrot (*Daucus carota*) germplasm collection.** K.E. Corak, R.K Genger, P.W Simon, and J.C. Dawson	8

4:20 pm **Wrap-up & planning for the 41st International Carrot Conference**

4:40 pm **Break-out to discussion groups**

6:00 pm **Dinner at the NWREC sponsored by Vilmorin-Mikado**

Tuesday, August 30 Field tour at WSU Mount Vernon NWREC, Ralph's Greenhouse, Washington Bulb Co., and other agricultural sites in Skagit Co.

Breakfast on your own

8:30 am **Meet at the NWREC for coffee and refreshments**

9:00 am: Walk to carrot cultivar demonstration at the NWERC (183 carrot cultivars)

10:30 am: Board buses for Ralph's Greenhouse

10:45 am: Welcome & overview of Ralph's Greenhouse by Ray de Vries, farmer. View 58 cultivars planted in organic carrot cultivar demonstration.

Noon: Board buses for Washington Bulb Co.

12:30: Box lunch and tour of Washington Bulb Co.

2:00 pm: Visit crops and other agricultural/scenic sites in Skagit Co.

5:30 pm: Return to NWREC

6:00 pm Dinner on your own

For those who registered for the additional field tour on August 31:

6:00 to 9:00 pm Carpool to hotels in Ellensburg

Wednesday, August 31 **Central Washington Field Tour** (pre-registered participants only)

Abstracts:

Oral Presentations

Experiences, learnings, and observations from 40+ years of carrot breeding

Roger E. Freeman
Nunhems USA, Brooks, Oregon, USA

In 1976, I first experienced carrot breeding at Texas A&M University and then was later fortunate to do my PhD work on carrots at the USDA/University of Wisconsin, before starting my career as a commercial carrot breeder in 1982 at Brooks, Oregon. Most vegetable breeders that have experienced these past 40 years are acutely aware of the significant changes that have occurred in the produce marketplace: the production shifts and consolidation, the transitions from OPs to hybrids, the application of new digital and genetic tools and the precision and efficiency improvements in farming and seeds. I hope to share some of my experiences and perspectives related to some of these shifts. This is from one career plant breeder, who's role was to adapt, evolve and learn enough to keep bringing new varieties to a changing marketplace of one species… carrots.

Creating connections, igniting inspiration and imagination, and having fun through Participatory Plant Breeding with carrots

Laurie McKenzie and Micaela Colley
Organic Seed Alliance, Port Townsend, WA, USA.

The Carrot Improvement for Organic Agriculture (CIOA) project addresses the critical needs of organic carrot farmers and producers by developing orange and novel-colored carrots for both the processing and fresh markets with improved disease and nematode resistance, weed competitiveness, nutritional value, visual appeal and flavor. Applying participatory breeding strategies to engage a broad spectrum of stakeholders in the trialing, breeding, and evaluation of the project materials has been successful and rewarding in numerous ways.

Participatory plant breeding (PPB) is a collaborative relationship between professional plant breeders, farmers, and other stakeholders (such as chefs, produce retailers, and consumers) to share knowledge, decision making and resources in breeding efforts. The CIOA project engages a wide range of stakeholders from elementary students and school garden coordinators, community gardeners and seed libraries to professional chefs, farmers and commercial seed companies. Creating such a wide and diverse network of collaborators has broadened both the reach and the impacts of the work as well as leveraging multiple environments for root production, selection and seed production. This unique and collaborative approach allows for breeding work to be conducted under multiple environments, providing the opportunity to breed for both specific and broad adaptation and improve yield stability throughout the development of new varieties.

Participatory plant breeding work also has tremendous social benefits and impacts. These benefits and impacts can be difficult to quantify and are often overlooked as important and valuable aspects of plant breeding work. The shared joy, inspiration, and connections that have emerged out of the PPB work in the CIOA project are indications of success and indicate that the impacts of the project and work will carry forth for many years to come.

Results of the carrot SCRI project: New phenotypes, markers, and genes in carrot germplasm to deliver improved carrots to growers and consumers

Phil Simon[1,2], David Spooner[1,2], Julie Dawson[2], Edgar Spalding[2], Sherry Tanumihardjo[2], Massimo Iorizzo[3], Phil Roberts[4], Allen Van Deynze[5], Theresa Hill[5], Daniel Sumner[6], Jas Sidhu[7], Lindsey du Toit[8], Timothy Waters[9], Micaela Colley[10], and Laurie McKenzie[10]
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In 2014, a survey of carrot stakeholders was conducted and a meeting was held to identify key traits important for improved carrot quality and productivity. This effort revealed that the carrot industry needs breeding stocks and genomic tools that can be used to develop carrots with improved field performance, including disease and pest resistance, and abiotic stress tolerance; and improved flavor and nutritional quality to better meet consumer needs. As a response to this survey, the USDA-NIFA Specialty Crop Research Initiative funded a project from 2016-2021 in which we phenotyped diverse carrot germplasm, including 694 diverse open-pollinated carrots from the USDA-NPGS and 70 breeding stocks, to discover and describe previously uncharacterized variation for important traits. Screening identified new sources of *Meloidogyne incognita*, *M. javanica*, *M. arenaria* and *M. hapla* nematode resistance, cavity spot (*Pythium violae* and *P. sulcatum*) resistance, and Alternaria leaf blight resistance (*Alternaria dauci*). Beyond disease and pest resistance traits, new genetic sources of drought and bolting tolerance, early stand establishment, improved flavor and sweetness, carotenoids, and anthocyanins were identified. The carotenoid dataset provided a foundation for identifying a new gene controlling nutritional carotenoid accumulation. Using plants identified with superior performance while phenotyping, breeding pools have been developed with elite nematode, Alternaria leaf spot and cavity spot resistance, drought tolerance, low-bolting incidence, large tops, vigorous stand establishment, excellent flavor, improved nutritional value, and unique color. To provide genomic resources to complement this phenotyping and pre-breeding effort, an expanded carrot genomic database, CarrotOmics, was developed for breeders to catalog genomic and phenotypic variation and track genes underlying important traits, and an improved genome assembly was developed. To advance studies on carrot nutritional quality, bioefficacy evaluation of pigments was completed in three nutrition evaluation studies, from which carrot was found to be effective at improving animal nutrition. To evaluate the economic impacts of new carrot traits on grower practices and costs, and consumer decisions, large U.S. surveys of self-reported carrot buyers were conducted. The retail buyers expressed a median willingness to pay about $0.21 per pound for the organic trait. Data for all traits from this project are being used for genome wide association studies (GWAS) analysis. Mapping populations were created for subsequent analysis, and the CarrotOmics database is being published.

Comparison of genotypic and phenotypic selection of breeding parents in a carrot (*Daucus carota*) germplasm collection

K.E. Corak[1,3,4], R.K Genger[1], P.W Simon[1,2], and J.C Dawson[1]
1 Department of Horticulture, University of Wisconsin-Madison, Madison, WI USA; 2 USDA-ARS, Vegetable Crops Research Unit, Madison, Wisconsin, USA; 3 USDA-ARS, Genomics and Bioinformatics Research Unit, Stoneville, MI USA; 4 Crop Science Department, North Carolina State University, Raleigh, NC USA.

Crop breeding programs interested in using genetic resources often have difficulty identifying useful accessions from germplasm collections. We explored genomic prediction strategies to more effectively use diverse germplasm, using ongoing efforts to breed carrot varieties with tall canopies and mild flavor as a model vegetable crop and breeding goal. Genomic prediction leverages high-density genotype data to predict phenotypes or breeding values, potentially allowing for rapid identification of useful germplasm in a genotyped collection. Two different training populations were designed to approximate different potential breeding contexts in which genomic prediction could be applied. Selected accessions were crossed to elite inbred lines to initiate new breeding populations. These populations were evaluated for canopy height and flavor and compared to populations developed from phenotypically selected parents. At the F2 stage, there were few differences between populations developed with genomic and phenotypic selection. While evaluation of future generations is required, these results suggest that genomic selection may allow for the identification of valuable germplasm accessions without the need for extensive field evaluation.

Leveraging diverse carrot germplasm to deliver genetic markers and improved stand establishment to growers

Jenyne Loarca, Julie Dawson, and Philipp Simon
USDA–Vegetable Crops Research Unit. Department of Horticulture, University of Wisconsin Madison, USA.

This study provides empirical evidence that visual evaluation of canopy coverage - a method that is intuitive, rapid, inexpensive, and grower-friendly – is valuable in measuring early-season carrot crop success. Carrot seedlings have a central role in early-season crop success, yet slow growth and poorly synchronized field emergence make carrot a poor weed competitor, producing small, unmarketable roots, resulting in food waste. Previous studies only evaluated top vigor on a few varieties or crosses; we expand on previous research by evaluating a cultivated *Daucus carota* diversity panel (N=695 accessions). This genetically diverse germplasm collection is maintained by the USDA's National Plant Germplasm System (NPGS), and contains seed sourced between 1947 to 2015 from 60 countries. We evaluated top-growth traits in multi-year field studies and found a wider range of variation for stand count than has been previously reported in carrot. We also make the first report of ranges for early-season canopy height (40 DAS) and early-season canopy coverage (50 DAS).

We also analyzed a high-germinating biennial subcollection (N=274) (which is relevant to industry breeders) and found stand count (41.3%) and canopy height (9.3%) are statistically significant components of early-season canopy coverage with high broad-sense heritability (H^2 = 0.76). We propose a method for characterizing germplasm and identifying accessions that contribute to both early-season crop establishment and end-of-season crop success (root yield). Furthermore, we used phenotypic data from our early-season field studies to perform Genome Wide Association Studies (GWAS). We generated single nucleotide polymorphic (SNP) markers using genotype-by-sequencing (GBS). In the subcollection (N=258), we found statistically significant markers for stand count, early-season canopy height, and early-season canopy coverage, each explaining 10-11% of early-vigor trait variation. Our results facilitate identification of carrot accessions that will contribute favorable genetics to improvement of stand establishment. These studies set the stage for development of breeding pools, with the long-term goal of delivering improved carrot cultivars to breeders, growers, and eaters.

Wild carrot germplasm sources of abiotic stress tolerance

Phil Simon[1,2], William Rolling[1,2], Adam Bolton[2], Aneela Nijabat[3], Aamir Ali[4], A.T.M. Majharul Mannan[5], M. Abdur Rahim[5]
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Carrot is an outcrossing crop with a wide range of genetic variation demonstrated for traits ranging from storage root color and shape, top size and architecture, growth rate, flavor, nutritional quality, disease and pest resistance, and abiotic stress tolerance. Most evaluations of genetic variation in carrot germplasm have focused on cultivated carrot landraces, heirloom cultivars, and local cultivars from global production regions. However, there has been a call for a much-expanded effort in collecting and evaluating the wild relatives of all crops to expand and enrich the genetic foundation of germplasm used for modern cultivar development. There have been limited evaluations of wild carrot germplasm (*Daucus carota* ssp. *carota, capillfolius*, and *gummifer*), primarily evaluating abiotic stress tolerance – heat, drought, and salinity. Most of those evaluations were made at seed germination with only ~30 wild carrot accessions from the USDA germplasm collection, evaluated at seed germination, and in those studies, minimal stress tolerance was noted in wild carrot, as compared to the cultivated carrot accessions included in the same studies. In contrast, in a study of 66 wild carrot accessions grown 60 days in hot, dry, and saline fields, plant growth and survival were superior to 'Brasilia' for several wild carrot accessions. And interestingly, wild carrots collected from drier and hotter locales demonstrated somewhat superior drought and heat tolerance than did accessions from collection sites with more moderate environments. Based on this latter study, a more extensive effort to evaluate wild carrot germplasm at later stages of plant development may reveal a broader range of genetic diversity useful for carrot genetic improvement and breeding.

Efficient production of transgene-free, gene edited carrot plants via protoplast transformation

C. M. Meyer[1], I. L. Goldman[1], E. Grzebelus[2], and P. J. Krysan[1]

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Gene editing is a valuable tool to create novel traits and generate genetic variation in plants. Gene editing can also have many practical applications in carrot breeding, such as the production of a haploid inducer for hybrid carrot production. However, major bottlenecks in the ability to transform and regenerate edited plant cells limit the efficiency and utility of gene editing for crop improvement. In addition, many gene editing methods involve stable incorporation of a transgene, which may cause continuous expression of the gene editing machinery or undesirable disruption of endogenous genes. Over the past three years we have developed a robust protoplast transformation and regeneration system and employed the system to transform carrot seedlings with a novel base editing construct, STU-CBE1. Protoplasts from young carrot seedlings (var. 'Dolanka') were co-transformed via PEG-mediated transformation with STU-CBE1 and sgRNAs targeting the Centromere Specific Histone H3 (*CENH3*) gene. Protoplasts were then cultured in liquid culture medium and underwent direct and indirect somatic embryogenesis to form somatic embryos. Within 4 to 5 months, seedlings were acclimatized to ex vitro conditions and the majority of plants survived acclimatization. In our first experiment 22/184 (11.9%) of seedlings contained mutations in *CENH3* and in our second experiment, 28 of 190 (14.7%) plants contained mutations in *CENH3*. This method therefore can efficiently generate a large amount of transgene free carrot plants with targeted point mutations. In addition, we are currently testing these mutants for their ability to cause haploid induction. Crosses were made between plants expressing a variant form of the CENH3 protein and plants expressing the WT protein. The progeny of these crosses are currently being screened to identify if any haploids exist. If these mutations were successful, CENH3-mediated haploid induction could be a method to create an *in vivo* haploid inducer for hybrid carrot production.

Effects of planting density on carrot root shape and QTL identification of root shape traits in biparental populations

Andrey Vega-Alfaro, Scott Brainard, Irwin Goldman
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Carrots are commercialized in market classes which depend mostly on root shape, but also on size and end-use. Despite its economic and research importance, little attention has been paid to the genetic architecture of carrot root shape and its interactions with planting density. Due to the limited understanding of the genetic structure of traits underlying market class, multiple cycles of selection are required to regain a desired shape. Breeders circumvent this problem by breeding mostly within a market class, limiting the use of inter-market class crosses. Advances in digital imaging for carrot phenotyping have improved the understanding of the root traits that comprise market class. Four key root traits were found to influence root shape: length, maximum width, root fill and length-to-width ratio (L/W). These traits were found to be significantly associated with several regions of the carrot genome in an association study using a diversity panel with over 600 genotypes. Root fill was associated with a single region of the genome on chromosome 2, explaining 6% of phenotypic variance. Root fill dictates the degree of filling along the length of the root and likely is an important component of root yield.

Biparental populations were generated to fine map previously identified root shape QTLs and identify novel QTLs related to root shape traits not captured in previous association studies including traits associated with the root shoulders and tip. Inbred parents with contrasting phenotypes included ‘L1408’ a long and narrow imperator type, ‘W133’ a processing type with medium-length and tapering root, and ‘W279’ a short Chantenay type with wedge-shaped root.

Field-based trials were conducted to analyze population density and genotype effects on root shape. Significant genotype effects were found on root fill and L/W in a generalized randomized complete block design with a factorial set of five genotypes representing the ‘Imperator’, ‘Chanteney’, ‘Danvers’, ‘Nantes’ and ‘Ball’ market classes and five planting densities ranging from 500,000 to 4,500,000 plants/ha. Planting density did not significantly affect root fill and L/W, but significantly influenced length and maximum width. High densities tended to produce marginally shorter (4%) and narrower (5%) carrots compared with low planting densities. No genotype x planting density interaction was observed for root fill, L/W or maximum width in field-based trails in muck soils.

Genetic mapping and field-based trials will help clarify the genetic architecture and the influence of planting density in root shape traits which classify carrots in different market classes.

Identification of an additional root-knot nematode (*Meloidogyne incognita*) resistance in a diverse collection of cultivated carrot (*Daucus carota* L.)

Kevser Ozel[1], William Rolling[2], Douglas Senalik[2], Thomas Horejsi[2], Shelby Ellison[1], William C. Matthews[3], Philip A. Roberts[3], Philipp W. Simon[2]
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2 Agricultural Research Service, United States Department of Agriculture, Madison, Wisconsin, USA; 3 Department of Nematology, University of California-Riverside, Riverside, California, USA.

Root-knot nematodes (RKNs) (*Meloidogyne* spp.) are one of the most problematic pests which attack the roots of various crops, including carrot, disfiguring roots, limiting growth, and thus leading to significant yield losses. With the root being the edible product, carrot (*Daucus carota* L.) has a particularly low RKN economic injury level, therefore RKNs are of great concern for carrot growers. Despite the availability of cultural management options, RKN management in carrot heavily relies on nematicides. Nematicides provide effective RKN control, yet carry the disadvantages of high cost, toxic effects, and harm to the environment and living organisms. Genetic resistance can be an essential control method to significantly and sustainably reduce carrot yield losses. Previously, two resistance loci limiting *M. javanica* attack, Mj-1 and Mj-2, were identified on chromosome 8, followed by a study which revealed five non-overlapping quantitative trait loci (QTL) limiting *M. incognita* attack on chromosomes 1, 2, 4, 8, and 9. A field trial conducted in Coachella Valley, CA, in 2017 confirmed rare occurrence of RKN resistance in a diverse collection of carrots. A South African plant introduction was observed to have the highest level of resistance and has been further evaluated. In a greenhouse trial, one month-old plants were inoculated with approximately 50,000 *M. incognita* eggs, and scored visually 60 days post-inoculation (dpi) on a 0 (resistant-no galls) to 8 (susceptible-severely galled) scale. Genome-Wide-Association-Studies (GWAS) were carried out to identify genetic loci contributing to nematode resistance within this plant introduction. This study revealed 2 unlinked major QTL possibly involved in conferring *M. incognita* resistance in carrot. Evaluation of biparental populations is underway.

Non-fumigated nematicides for the management of root-knot nematodes in carrots

Jaspreet Sidhu, Jed Dubose, and Jennifer Fernberg
University of California Agricultural and Natural Resources, Bakersfield, California, USA.

Root knot nematodes (RKN), *Meloidogyn*e spp. are the most important plant parasitic nematodes affecting the fresh market carrot production in California. The root-knot nematodes can cause substantial damage by stubbing, forking, and galling the roots thereby reducing marketable yields. The galled feeder roots are unable to sustain the water and nutrient needs of the plants leading to yield reduction. Currently, there are no resistant cultivars available for the California carrot industry and management has mainly relied on the use of pre-plant soil fumigants such as Telone II (a.i. 1,3-dichloropropene) and metam sodium or metam potassium. However, new fumigant regulations by the Department of Pesticide Regulations (DPR) have been put in place and due to these regulations, substantial parts of the field or the entire field may not be treated by fumigation because of buffer zone requirements. New nematicides with novel modes of actions have emerged from major agricultural chemical companies in the last few years that have shown excellent performance in managing RKN. Fluazaindolizine (Corteva), fluensulfone (Adama), fluopyram (Bayer), and a new developmental Product (Syngenta) have shown excellent nematicide properties in the field trials conducted in moderate to high RKN infested soils. These new chemistries have effective new modes-of action, lower mammalian toxicity, and lesser environmental impacts than previous generations of nematicides.

How effective are mycorrhizae inoculants for improving yield and disease resistance in carrots?

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1 Department of Plant Agriculture, University of Guelph, Guelph, ON, Canada; 2 Department of Plant Pathology, Washington State University, Mount Vernon, WA, USA.

Several commercial formulations of mycorrhizal fungi are available to vegetable growers. Most contain *Rhizophagus irregularis* (N.S. Schenck& G.S. Sm.) C. Walker &A. Schuessler (formerly *Glomus intraradices* N.S. Schenck& G.S. Sm.) in a granular form, as in the product AGTIV, or a formulation that can be applied to seed. The objective was to determine if these treatments improve yield or reduce diseases in carrot production in the Holland Marsh, Ontario, Canada. Trials were conducted in 2017 and 2018 on high organic matter 'muck' soil (71% om, pH 6.3, 136 ppm phosphorous (P)) and mineral soil (2.6% om, pH 7.6, 40 ppm P). Seed of carrot cv. Cellobunch was obtained with *R. irregularis* (2-4 propagules/seed) inoculated on the seed and compared to AGTIV granular inoculant (240 propagules/g). Granular AGTIV was applied at the recommended rate of 0.5 g/m row or 1 g/m row. On mineral soil, additional treatments were no P or 50 kg/ha P applied preplant as monoammonium phosphate. No P was applied to the muck soil because the P was already excessive. Severity of carrot leaf blight was assessed four times from August to mid-September. Leaf P content was assessed on the youngest mature leaf in late July, and root tissue P was assessed at harvest. Yield and marketable yield were recorded. Mycorrhizal colonization of roots was quantified in 2018. There were no differences among treatments. Percent mycorrhizal colonization ranged from 34.2-44.8%. Phosphorous content of carrot foliage grown on mineral soil was greater in the check plots plus P compared to the check plots without P (0.32 vs 0.27%), and neither were different from the mycorrhizae treatments (0.29%). Root P content ranged from 0.37-0.40%. The only difference in disease severity was found on muck soil in 2018, where the disease severity index of plants that grew from treated seed was less (60%) than that of the untreated check plots (69%). There were no differences in total or marketable yield on either soil in either year. Yields were acceptable for the area. In 2017, marketable yield ranged from 39-52 and 60–68 t/ha on mineral and muck soil, respectively. Applying 50 kg P/ha to mineral soil did not increase yield. In 2018, yield ranged from 25–43 t/ha on mineral soil and 84-88 t/ha on muck soil. The mycorrhizae treatments did not improve carrot yield. The high level of P in the soils may have inhibited mycorrhizal colonization of carrot roots.

The effect of seedborne *Xathomonas hortorum* pv. *carotae* on seed germination and seedborne transmission of bacterial blight in carrot

Jeremiah Dung[1,2] and Jeness Scott[1,2]
1 Central Oregon Agricultural Research and Extension Center, Oregon State University, Madras, Oregon, USA; 2 Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oregon, USA.

Bacterial blight caused by *Xathomonas hortorum* pv. *carotae* (*Xhc*) is an economically important disease of carrot. The disease results in lesions on leaves and stems and can reduce yield. The pathogen can also be seedborne and infested seed is considered to be an important source of inoculum. Existing seed contamination thresholds for *Xhc* used by the carrot seed industry were developed using artificially-infested seed inoculated at a uniform rate and blended with healthy seed. However, previous research revealed that the incidence of *Xhc*-contaminated seeds can vary drastically within and among naturally-infested commercial carrot seed lots, ranging from 8 to 98%. Additionally, a relatively few number of seeds can harbor high populations of the pathogen (>10^5 CFU/seed). A re-evaluation of seed contamination and seed transmission thresholds is needed to better understand the epidemiological and market implications of these new findings. This project used naturally-infested seed to investigate: 1) the effect of seedborne *Xhc* on carrot seed germination; and 2) the level of *Xhc* required on an individual carrot seed to transmit the pathogen to carrot seedlings. Seeds from four commercial carrot seed lots representing three proprietary hybrid carrot lines were obtained. Carrot seeds were individually assayed on XCS medium to identify seeds with varying levels of natural infestation (ranging from 0 to 3.6 x 10^7 CFU/seed). The same seeds were then planted in 6-cell trays containing greenhouse potting mix and placed in a growth chamber (28/18°C day/night and 90-100% relative humidity). Flats were covered with clear plastic domes until germination. Seedlings were harvested at the 2-3 leaf stage and individually assayed to determine the level of *Xhc* on each seedling. Pathogen transmission from seed to seedling was not observed for individual seeds that harbored ≤ 10^1 CFU, and the pathogen was only detected on 9% of seedlings grown from individual seed with > 10 and ≤ 100 CFU. Transmission of *Xhc* from seed to seedling was greater in seed harboring larger pathogen populations, with pathogen transmission rates ranging between 20% (for seed containing 10^2 to 10^3 CFU/seed) to 67% (for seed containing 10^4 to 10^5 CFU/seed). Germination rates for seed harboring between 10^2 and 10^6 CFU ranged from 50 to 71% compared to seed non-detectable levels of the pathogen (80%). Overall, this study provides additional insights into the quantitative effect of seedborne *Xhc* populations on seed health and bacterial blight risk in carrot and carrot seed crops.

Characterizing internal carrot leaf colonization patterns by *Xanthomonas hortorum* pv. *carotae*

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1 Department of Plant Pathology, The Ohio State University, Columbus OH, USA; 2 Infectious Diseases Institute, The Ohio State University, Columbus OH, USA; 3 Department of Plant Pathology, Washington State University, Mt Vernon, WA, USA; 4 Department of Botany and Plant Pathology, Central Oregon Agricultural Research and Extension Center, Oregon State University, Madras, OR, USA.

The plant pathogen *Xanthomonas hortorum* pv. *carotae* causes bacterial blight of carrot (*Daucus carota* subsp. *sativus*). Bacterial leaf blight includes water-soaked lesions that are chlorotic and can become necrotic, resulting from high levels of bacterial infection. The mechanisms for *X. hortorum* pv. *carotae* to enter leaves and spread internally remain under-explored. We, therefore, evaluated *X. hortorum* pv. *carotae* colonization of the leaves of both susceptible and resistant carrot cultivars. We determined by counting culture-based colony forming units that bacterial levels were greater in susceptible compared to resistant cultivars. This was consistent for both infiltration of leaves with a blunt syringe or a more natural form of infection following spray inoculation. We validated our findings with laser confocal imaging in which we observed green fluorescent protein (GFP)-expressing *X. hortorum* pv. *carotae* levels increased and spread within leaves of susceptible cultivars; while the bacteria remained localized in leaves of resistant cultivars. We will show time-lapse video imaging to demonstrate these findings. We used confocal imaging and scanning electron microscopy to determine that the primary natural entry point for *X. hortorum* pv. *carotae* foliar infection is through stomata gas exchange pores. This research sets a platform for defining the tissue-specific entry and spread of *X. hortorum* pv. *carotae* in leaves of both susceptible and resistant carrot cultivars in the hopes of characterizing seed colonization in the future.

The places *Xanthomonas* will go: Examining *Xanthomonas hortorum* pv. *carotae* in airborne debris and on non-carrot crops in central Oregon

Katelyn Baldino [1], Matthew Huckins [2], Jeness Scott [1,3], Rob Stoll [2], Eric Pardyjak [2], Walter Mahaffee [4], and Jeremiah Dung [1,3]
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Bacterial blight of carrot is caused by the pathogen *Xanthomonas hortorum* pv. *carotae* (*Xhc*). The pathogen negatively affects carrot seed crops by infecting the leaves, umbels, and seeds of carrot plants. In addition to potentially reducing seed quality and yield, *Xhc* reduces the marketability of carrot seed due to phytosanitary restrictions. Carrot seed crops are typically planted in August and harvested in September of the following year, resulting in a potential green bridge between seasons. There are also other crops that potentially can serve as reservoirs of epiphytic *Xhc* populations in Oregon. The objectives of this research were to: 1) characterize the potential of carrot seed crop debris as a source of inoculum; and 2) determine if *Xhc* can become established on other crops that are grown in carrot seed production systems. For objective 1, custom sampling traps were deployed to capture airborne particles ranging from above 400 to below 100 microns during a harvesting event. When subjected to a qPCR assay, *Xhc* genomes ranged from undetectable levels to 2.6 x10^4 *Xhc* genomes per filter. While statistically similar amounts of *Xhc* were recovered from all particle sizes, distance from dust source had a significant effect on *Xhc* detection, with more *Xhc* detected at 3 and 9 meters from the traps compared to 27 meters (α=0.05). Pathogenic isolates of *Xhc* were recovered from all size class filters, and debris applied to carrot plants in a greenhouse resulted in epiphytic colonization. For objective 2, field sampling in 2021 of crops grown adjacent to carrot seed fields in central Oregon demonstrated that *Xhc* was detectable on alfalfa, Kentucky bluegrass, forage rye, and parsley root. To examine whether *Xhc* is a resident or transient epiphyte recoverable from these crops, a greenhouse experiment featuring crops common to central Oregon was conducted. Carrot, parsley seed, parsley root, Kentucky bluegrass, mint, roughstalk bluegrass, alfalfa, and wheat were inoculated with *Xhc* (1.8 x 10^7 CFU total) and then destructively sampled (1, 7, 14, and 27 days post-inoculation) to evaluate the *Xhc* populations over time. All crops supported similar levels of *Xhc* at the final timepoint, with the exception of mint and alfalfa (α=0.05), based on qPCR assay results. None of the crops exhibited symptoms at any sampling point. This suggests that *Xhc* epiphytically and asymptomatically colonizes non-carrot crops. A better understanding of the ecology and epidemiology of *Xhc* will allow for better season-long risk assessment of disease transmission.

Abstracts: Poster Presentations

Dreamy flavor across the carrot rainbow: Participatory methods to select carrots for culinary quality, beauty, and productivity on organic farms.

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Carrots are a nutritionally and economically important vegetable crop for the organic sector, ranking fifth in annual U.S. organic vegetable sales at $132 million USD in 2019, and first in farm gate value among vegetable crops in Canada at over $133 million CAD in 2019. Carrot production challenges overlap between organic and conventional systems, but the management practices and prioritization of cultivar traits often differ. In particular, recent surveys of organic carrot growers ranked breeding for weed competition and flavor as top priorities for carrot improvement. Organic consumers often prioritize novel appearance, and while carrot nutrition has been improved across multiple color classes, it is critical to simultaneously improve flavor to meet organic market demands.

This interactive carrot tasting, display table, and poster presentation will describe and demonstrate the work of two projects – Carrot Improvement for Organic Agriculture (CIOA) and Canadian Organic Vegetable Improvement (CANOVI) – working to improve carrots for organic farms and markets in the United States and Canada. CIOA is a long-term breeding project led by Organic Seed Alliance (OSA), USDA-ARS, and University of Wisconsin-Madison that addresses the critical needs of organic carrot farmers by developing orange and novel-colored carrots with improved disease and nematode resistance, weed competitiveness, nutritional value, and flavor. CANOVI is a farmer-researcher collaboration led by the Bauta Family Initiative on Canadian Seed Security and University of British Columbia that seeks to improve vegetable varieties for Canadian organic farms. Its carrot projects aim to strengthen Canadian seed security by creating robust, flavorful, open-pollinated cultivars that can be produced for both roots and seed on organic farms in Canada. Both CIOA and CANOVI incorporate participatory plant breeding approaches, involving farmers, chefs, and/or consumers in determining breeding priorities, evaluating lines during development, and making selections from breeding populations. OSA and CANOVI co-host a Carrot Breeding Network on the Organic Seed Commons platform, which facilitates grower-to-grower communication about carrot breeding and seed production.

Attendees will be invited to sample and evaluate carrot varieties selected through the CIOA and CANOVI programs. Evaluation for overall liking, sweet flavor, harsh flavor, and texture will take place via the SeedLinked platform, which attendees may access freely on their mobile devices via a QR code. A display table will showcase CIOA, CANOVI, and commercial comparison carrot varieties, along with live tasting results. Two academic posters, along with handouts and electronic displays, will describe each program's goals, participatory methods, and progress to date.

Is the soil microbiome related to the risk of cavity spot on carrots?

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Cavity spot is an economically important disease of carrots with a worldwide distribution. The disease appears as sunken, horizontally elongated lesions on carrots. Usually, these lesions appear near harvest and there are no above-ground symptoms. Symptomatic carrots are unmarketable. The disease can be caused by several species of soilborne *Pythium*. Management recommendations are limited to avoiding problematic fields and applying fungicides prior to or during seeding if the field has a history of cavity spot. However, there are no diagnostic tools to identify high risk fields. Many studies have shown that the risk of the disease is not related to the total quantity of *Pythium* species in soil. The hypothesis is that some aspects of the soil microbiome, along with pathogen presence, influence the development of cavity spot. The objective was to determine if there is a relationship between the soil microbiome, soil chemical properties, and the risk of cavity spot. Six growers' fields in the Holland Marsh, Ontario, were identified as having low or high risk of cavity spot. Soil was collected from each field just before or at carrot seeding. Assessment of carrots at harvest confirmed the accurate selection of low and high-risk fields. Cavity spot severity in low-risk and high-risk fields was 15–21% and 38–55%, respectively. A comparative metagenomic analysis conducted by Harvest Genomics, Quebec, showed that microbial communities were different in the soils with high vs. low risk of cavity spot. The relative abundance of the following microbes was less in high-risk soils vs low-risk soils: the fungi *Mortierella, Tetracladium, Penicillium*, and *Fusarium*; the bacteria *Bauldia* and *Rhizobium*; and the oomycetes *Phythophthora, Albugo,* and *Peronosporales*. Furthermore, the low-risk soils had a higher average soil pH of ~7 and soil calcium content of 8,400 ppm compared to high-risk soils that had an average pH of ~5.8 and calcium content of 3,800 ppm. There was no significant association of organic matter or other soil nutrient concentrations with cavity spot risk. Soil pH and calcium were correlated significantly with the composition of fungal and bacterial communities but there was no significant correlation with oomycetes. The results suggest that the taxa identified, along with soil pH and calcium content, could be used as indicators of cavity spot risk. Assessment of additional fields is in progress to validate these results. A method to assess the risk of cavity spot in fields before seeding would be very useful for growers.

Development of automatic irrigation system for effective selection of carrot cavity spot disease tolerance

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Cavity spot disease of carrots caused by *Pythium* species is one of the most disastrous diseases in Japan because it reduces the quality of carrots so that they become unmarketable and result in economic losses for farmers. It is known that much soil moisture elevates the risk of this disease. Because Japan has much rain in the harvest season, carrot varieties which are tolerant to cavity spots are needed.

In the field, it is difficult to evaluate disease tolerance accurately because soil texture or soil moisture are different depending on location. Thus, I have developed the selection system by using planters and soil moisture measuring sensors. I used cost-effective soil moisture sensors and tried to irrigate automatically according to the value of the sensors. Solenoid valve which controlled water pumps were managed by small computers (Raspberry pi, Arduino). Finally, I was able to develop a system which could manage up to 6 planters individually, and made it possible to visualize on smartphones not only soil moisture values but also greenhouse temperature, humidity and soil temperatures.

Using this irrigation system, I cultivated three different kinds of carrot varieties in the soil which contained cavity spot disease pathogen. The soil moisture was kept in a dry, wet, and damp condition. In the result, the disease appeared more sever in the wet condition than the dry and damp condition. The difference of disease tolerance between the varieties was consistent with the field tests. Therefore, it seems that I will be able to select disease tolerant varieties by using this system.

The system I am introducing in this poster consists of parts which can be bought at home improvement stores or electronic commerce sites. There are many important traits affected by soil moisture such as drought tolerance or shoulder deformity. This irrigation system will contribute to evaluate these traits easily and cost-effectively in plant breeding.

Carrot cyst nematode population growth in the Holland Marsh, Ontario, Canada

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The carrot cyst nematode (CCN), *Heterodera carotae* (Jones), is a carrot yield-robbing nematode commonly found in the high organic matter (muck) soils of the Holland Marsh, Ontario, Canada, and also found in organic soils in Michigan State, U.S.A. The nematode parasitizes carrot and wild carrot roots causing the carrots to become forked, stunted or smaller in size. To date, CCN has not been identified in any mineral soils in Ontario. The nematode has been found in 90% of fields sampled in the Holland Marsh, but not in any muck soils in other regions of the province. Commercial fields of carrots and onions were assessed for the presence of CCN in the Marsh and the population change over seasons was tracked. A two-year carrot and onion rotation is common in the Holland Marsh. Between 2016 to 2021, fields were soil sampled in the Fall in an X pattern by collecting 20 cm soil cores. Juvenile, male and female CCN were extracted from the soil and quantified. Juveniles and males were extracted using a modified Baermann pan method. Female cysts were extracted using the Fenwick method. In 2018, the number of cysts in carrot fields ranged from 0 to 6420 per kg soil. The number of juveniles was always higher than the number of cysts, and there were generally low numbers of male CNN. In most years, onion fields were also sampled that had carrots the previous year. The number of cysts in fields with CCN generally increased each year, even in an onion crop that followed a carrot crop. From 2016 to 2021, two fields following a continuous carrot and onion rotation were sampled annually to track CCN population changes. The same trend was found. The increase in cysts from carrots to onions is likely due to a maturation process of cysts on fine carrot roots in the fall which cannot be recovered at the time of sampling. Female cysts have been found to contain around 63 eggs per cyst. These eggs can remain viable for many years, which allows populations to build each year. Very few juvenile and male CCN were recovered after an onion or any non-carrot crop. Future research focused on the development, efficacy and registration of nematicides is necessary to manage the growing populations of CCN in the Holland Marsh.

Monitoring and controlling carrot weevil in the Holland Marsh, Ontario

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Carrot weevil (CW), *Listronotus oregonensis* (LeConte), is a major pest of carrots in the Holland Marsh, Ontario, Canada. Adult CW become active in the early spring and deposit eggs in leaf bases and young carrot roots. Weevil larvae feeding on young carrots can kill seedlings outright. Larval feeding damage to larger roots is concentrated on the top third of the root and renders the carrot unmarketable. Carrot weevil damage increased continuously from 1.7 to 6.9% between 2010 to 2016 in the Holland Marsh. Monitoring and insecticide efficacy trials conducted at the Ontario Crops Research Centre – Bradford between 2015 to 2019 found that CW had become resistant to the commonly used insecticide phosmet (Imidan), but foliar applications of novaluron (Rimon) and cyantraniliprole (Exirel) resulted in reduced CW damage. These products were most effective in high pressure fields when applied at both the 2nd and 4th leaf stage. The adoption of novaluron helped reduce the amount of CW damage in commercial fields to 0.2% by 2021. This research contributed to the registration of cyantraniliprole in 2019. The use of these two new actives continues to minimize CW damage and provides products with different modes of action to be used in rotation. Carrot seeding date trials were conducted to determine if CW damage could be avoided. The studies found that carrots seeded in late May to early June had lower CW damage compared to carrots seeded earlier in May. Seeding carrots later in the season may be an effective cultural practice to minimize carrot weevil damage. The seeding date results show that monitoring and applying insecticide is very important for the management of CW in early seeded carrots. Monitoring is still useful for late seeded carrots, to determine if insecticides are needed or not. Monitoring of CW feeding throughout the season has also observed a probable second generation of CW. Managing CW in the Holland Marsh has been successful through combining optimum timing of these effective insecticides and, in some cases later seeding, to reduce the majority of CW damage.

Does resistance to cavity spot in carrot confer resistance to forking?

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Cavity spot of carrot is caused by a number of *Pythium* species, primarily *P. sulcatum* and *P. violae*. Pythium root dieback (PRD) of carrot is also caused by several *Pythium* species, mostly *P. ultimum*, *P. irregulare* and *P. sulcatum,* although the role of the various species in this phenomenon is not well documented and other factors can cause forking of carrot roots. PRD often results in forked roots, which are not marketable. As part of a USDA breeding program to improve the resistance of carrots to cavity spot, the role of *Pythium* species in cavity spot and PRD is also being investigated. The trials established to assess cavity spot were also used to assess if resistance to cavity spot might also confer resistance to forking. Breeding lines and commercial cultivars were evaluated for percent forked carrots in cavity spot nurseries from 2018 to 2021 in Ontario, Canada, and in 2021 in Washington State. Carrots were direct-seeded in naturally infested, high organic matter soil (65-74%) in Ontario in June each year and harvested in October. In Washington State, a mineral soil field site (4.5% organic matter) was established as a cavity spot nursery. The site has been inoculated annually with *P. sulcatum* and *P. violae* since 2018. Carrots were direct-seeded in May and harvested in October. Cavity spot severity ranged from 0-59% and forked roots from 0 – 59% at this site. In Ontario, cavity spot ranged from 0-70% and forking from 0-40%. There was no relationship between cavity spot and forking in the Washington State trial (r = -0.01) and very little relationship in the Ontario trials (r = 0.01 to 0.24). This indicates that resistance to the Pythium species causing cavity spot does not confer resistance to those species involved in PRD. However, the species involved in PRD, or carrot forking in general, could not be confirmed, as is common with this disease. Some breeding lines were identified that had low incidence and severity of cavity spot and a low incidence of forking, demonstrating that carrot lines can be selected for resistance to both diseases.

Evaluation of bactericides for Bacterial Blight Control in carrots

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Bacterial leaf blight, caused by the bacteria *Xanthomonas campestris* pv. *carotae* can be a significant problem in certain carrot production areas in California. The best way to manage and prevent introducing these diseases into the field is by planting disease-free or indexed seed. However, planting healthy or treated seed may not always prevent the disease because the bacteria can survive in soil on plant debris and can be spread by splashing rain, irrigation, and insects. Copper-based fungicides are used to manage bacterial blight if foliar treatments are warranted for management. However, copper-based bactericides are most effective when used as preventative treatments and have limited ability to manage the pathogen once the disease is established in the field. The objective of this research was to evaluate potential post-plant foliar treatments to manage the disease in-season.

CIOA3 – Carrot Improvement for Organic Agriculture: Leveraging on-farm and below ground networks

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Organic carrots accounted for 25% of total carrot acres and 13% of sales in 2018. As organic produce sales increase annually, market supply tends to fall short of consumer demand. By involving researchers and stakeholders from key regions of organic carrot production, the CIOA3 project addresses the critical needs of organic carrot producers to better meet that demand by developing orange and novel-colored carrots for fresh market and processing with improved traits for organic systems. CIOA3 is a USDA-NIFA OREI project that builds upon accomplishments of the CIOA1 and CIOA2 projects. To address organic producers' needs for improved pest and disease resistance in orange and novel-colored carrots, new genetic sources of root-knot nematode and Alternaria leaf blight control are being developed. In a survey of important crops and traits to breed for in organic systems, organic carrot growers ranked breeding for weed competition and for flavor as top priorities. To address organic producers' needs for improved weed competitiveness in carrots, breeding stocks with vigorous growing seedlings and large tops are being developed. To address organic industry needs for improved flavor and nutrition in carrots, flavor and nutritional value are top priority consumer quality traits under selection in the development of new breeding stock. A diverse array of microbes occur in carrots and the soils they grow in, and crop genotype can also play a role in leveraging the benefits of healthy soils. To leverage healthy soil microbiomes to promote nutrient-use efficiency, prevent pests, and improve the quality and storability of carrot taproots, expanded studies of soil microbiomes are underway in CIOA3. This research will characterize carrot-microbe interactions to identify mechanisms regulating these genetic differences and to determine how carrot microbiomes can influence the quality and storability of roots to integrate selection for these relationships in carrot breeding programs. Outreach and research objectives of CIOA3 to achieve these goals will include conducting a participatory systems approach to breeding and on-farm assessment. The virtual networking platform, Organic Seed Commons serves as an online synergy space for coordination of organic carrot stakeholder participation in project activities (www.organicseedcommons.org). CIOA3 researchers will partner with eOrganic to deliver online extension resources and will release new publicly available cultivars and breeding lines to the organic seed industry that address critical needs prioritized by organic stakeholders.

Public-private partnership investigating European carrot genetic resources in EVA Carrot

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1 Rijk Zwaan, France; 2 Warwick University, UK; 3 Bejo Zaden B.V., The Netherlands; 4 Vilmorin, France; 5 Sementes Vivas, Portugal; 6 NordGen, Sweden; 7 OBS, France; 8 BPGV-INIAV, Portugal; 9 CITA-Aragón, Spain; 10 Julius Kuehn Institute, Germany; 11 Carosem, Italy; 12 Takii, France; 13 BASF Vegetable Seeds, The Netherlands; 14 Institut Agro, France; 15 ECPGR and Alliance Bioversity-CIAT, Italy.

The European Cooperative Programme for Plant Genetic Resources (ECPGR) aims at ensuring the conservation and utilization of plant genetic resources in Europe through collaborative activities. The ECPGR European Evaluation Network (EVA), established in 2019 with financial support from Germany, brings together different stakeholders in public-private research partnerships to jointly evaluate crop accessions held in European genebanks. In collecting phenotypic and genotypic information of often poorly characterized and consequently underutilized genetic resources, EVA facilitates their use in breeding programs. EVA thus promotes sustainable use of Plant Genetic Resources for Food and Agriculture, harnessing existing agrobiodiversity to facilitate adaptation of European agriculture to climate change and to contribute towards achieving related Sustainable Development Goals (SDGs).
One of five crop-specific EVA networks, EVA Carrot (https://www.ecpgr.cgiar.org/european-evaluation-network-eva/eva-networks/carrot) joins fourteen partners from seven European countries, including eight private breeding companies working together at the pre-competitive stage. Following up on the activities of the ECPGR project CarrotDiverse, the consortium evaluated a diversity panel of sixty carrot accessions from four genebanks in multilocation trials across Europe in field, greenhouse and laboratory over two years to create in-depth characterization and evaluation data with an emphasis on biotic stresses and agronomic traits of interest for breeders. Genotyping these accessions with a combination of Genotyping by sequencing (GBS) and Whole genome sequencing (WGS) generated valuable data for association studies.

All network partners bring their relevant expertise to the project and thus, working together on these evaluations, the network jointly creates a vast pool of knowledge which will be useful in developing carrots suitable for diverse agro-ecologies and able to cope with the challenges of a changing climate. Here we present initial results from the EVA carrot network and perspectives for an improved management and valorization of genetic resources.

40th International Carrot Conference: Field Tour, 30 August 2022

A. Conventional Carrot Cultivar Demonstration

Aerial photo taken on 29 July 2022 by Kwabena Sarpong, WSU PhD student

Location: Field D2 North, Washington State University Mount Vernon NWREC, 16650 State Route 536, Mount Vernon, WA 98273, USA.
183 cultivars: 2 beds/cultivar, with 2 rows/bed x 25 feet (7.6 m). 10-inch (25-cm) row spacing in the beds. Low-density bed: ~400,000 seed/acre (1M seed/ha). High-density bed: ~1.5M seed/acre (3.75M seed/ha).
Planted: 28 April 2022 with a 4-row Jang planter. Beds 22 inches wide x 12 inches tall (55 cm x 25 cm). Seed placed 0.5 inches deep (1.25 cm). *Four tropical cultivars (plots 57-60) planted on 17 May with a 1-row Jang push-planter.*
Border beds: Cultivars Duquesa (Sakata) on north border, Narvik (Bejo) on south border, and Jerada (Rijk Zwaan) on most east and west borders.
Herbicides: Treflan (trifluralin) applied PPI on 27 April, Fusilade DX (fluazifop-P-butyl) on 21 May, Caparol 4L (prometryn) on 29 May, Rely 280 (glufosinate-ammonium) in alleys and between beds on 15 June, and Caparol 4L (prometryn) on 21 June. Lots of hand-weeding!
Irrigation: Hand-lines (~1x/week from June). **Fertilizer:** Pre-plant broadcast application of 46-0-0 at 270 lb/acre (303 kg/ha) incorporated on 27 Apr.
Trial assistance: Lindsey du Toit, Michael Derie, Babette Gundersen, Tomasita Villarroel, Bob Hulbert, Doug Jensen, Alex Batson, Marilen Nampijja, and Kayla Spawton (WSU), and Jacob Slosberg and Tim Terpstra (Gowan Seed Co.).

40th International Carrot Conference:

Conventional cultivar demonstration planted at WSU Mount Vernon NWREC on 28 April 2022, except 4 tropical cultivars (plots 57-60) planted on 17 May.

Type/market	Company	Plot	Cultivar	Additional information from supplier	Notes
Imperator cellos	Bejo Seeds, Inc.	1	Junction F1 (Bejo 3187)		
		2	Jefferson F1 (Bejo 3188)		
		3	Jackson (Bejo 3136)		
		4	Istanbul F1		
	Integra Hybrids, LLC	5	KXPC 020		
		6	WIC 106		
		7	WIC 111		
	Nunhems USA Inc.	8	Maverick		
		9	Rebel		
		10	TrophyPak		
		11	Trooper		
	Pop Vriend Seeds B.V.	12	Jacinto (PV 5041)		
	Rijk Zwaan	13	Ymer		
	Seminis Vegetable Seeds	14	Envy		
		15	OrangeBlaze		
		16	SV2384DL		
		17	SV4128DL		
	Vilmorin	18	Yosemite		
	USDA ARS, Phil Simon	19	19'B111-3	(B9304 × F7738) × Nb8524B	
		20	19'B113-3	(B6274 × F7737) × F5367B	
		21	19'B113-4	(2566 × F7737) × F5367B	
		22	17'788-3	(2126A × L3303B) × Npbw7261B	
		23	17'788-5	(5280A × Nbh2306B) × Npbw7261B	
Imperator cut 'n peel	Bejo Seeds, Inc.	24	Pontiac F1		
		25	Pittsburgh F1		
		26	Pomona F1 (Bejo 3185)		
		27	Pismo Fa (Bejo 3186)		
	Illinois Foundation Seeds, Inc.	28	FCR 17720		
		29	FCR 17724		
		30	FCR 17748		
		31	FCR 17749		
		32	FCR 17750		
		33	Viper		
	Integra Hybrids, LLC	34	KXPC 107		
		35	KXPC 520		
		36	KXPC 650		
		37	WIC 703		
		38	WIC 716		
	Nunhems USA Inc.	39	CrispyCut		

Type/market	Company	Plot	Cultivar	Additional information from supplier	Notes
		40	HighCut		
		41	HoneySnax		
		42	ReadyCut		
		43	SugarSnax		
	Pop Vriend Seeds B.V.	44	Olancha (PV 5304)		
		45	PV5311		
		46	PV5656		
	Seminis Vegetable Seeds	47	CRC1706		
		48	PS 1441		
		49	SVDC1978		
		50	SVDC2089		
		51	SVDC4193		
	USDA ARS, Phil Simon	52	19'B112-3	(L1138 × L3303) × Nbh2306B	
		53	14'475-3	(7551 x 1131) x 9785	
		54	14'477-5	(9253 x 9788) x 9788	
		55	17'790-5	(L1406A × L0567B) × Nbh2306B	
		56	17'790-6	(L9793A × L3726B) × Nbh2306B	
Nantes	Agristar do Brazil Ltda	57	TPC 10791	Tropical type, planted 19 d later	
		58	TES 19390	Tropical type, planted 19 d later	
		59	TPC 21882	Tropical type, planted 19 d later	
		60	TPC 21884	Tropical type, planted 19 d later	
	Bejo Seeds, Inc.	61	Naval F1	Cello, slicer	
		62	Newhall F1	Cello, slicer	
		63	Norway F1	Late Nantes	
		64	Navedo F1	Late Nantes, slicer	
	Carosem GmbH	65	Caravel F1		
		66	CA 9647 F1		
		67	CA 678 F1		
		68	CA 6572 F1		
	Illinois Foundation Seeds, Inc.	69	FCR 14411		
		70	FCR 16619		
		71	FCR17653		
		72	FCR17663		
		73	FCR19054		
		74	FCR19055		
		75	FCR19057		
		76	Duquesa		
	Integra Hybrids, LLC	77	KXPC 133		
		78	WIC 203		
		79	WIC 208		
		80	KXPC 310 (WIC 310?)		
		81	KXPC 317 (WIC 317?)		
		82	KXPC 603 (WIC 603?)		

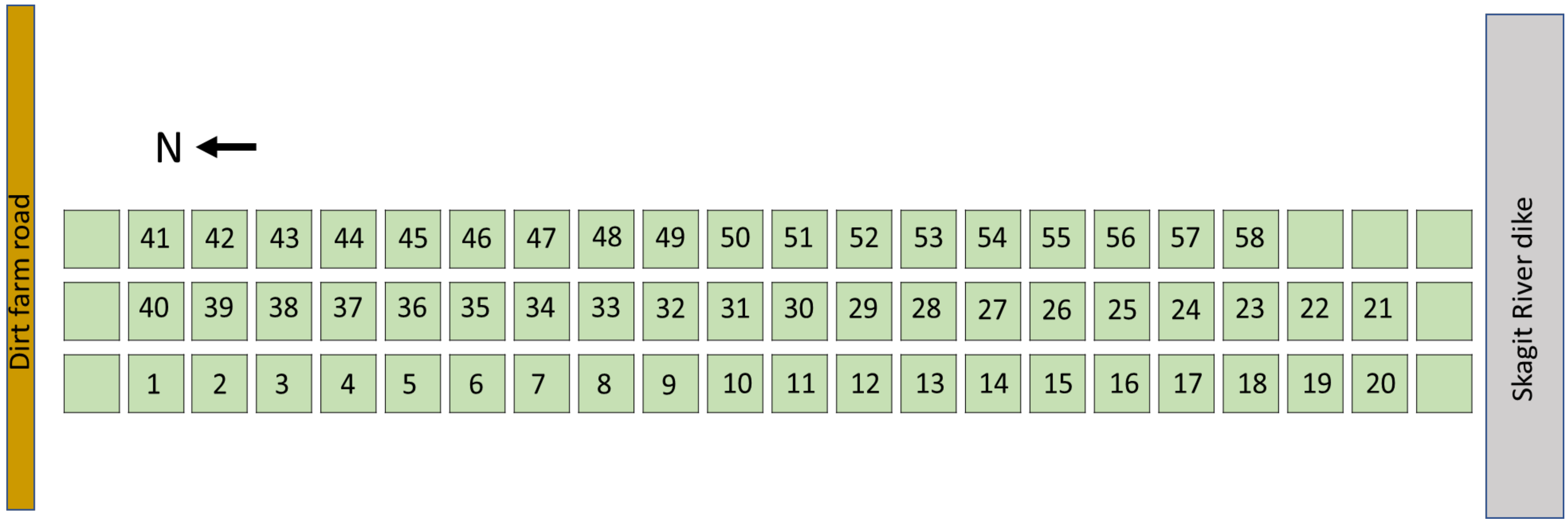
Type/market	Company	Plot	Cultivar	Additional information from supplier	Notes
	Nunhems USA Inc.	83	Allyance		
		84	Brillyance		
		85	Romance		
	Organic Seed Alliance	86	Fantasia		
		87	Orange Flavor Pop'n		
		88	Orange Strain Pop'n		
		89	PYP Dark Pop'n		
		90	R6220		
		91	R6336		
		92	YEH1		
	Pop Vriend Seeds B.V.	93	Bryce (PV 5412)		
		94	PV5455		
		95	PV5457		
	Pure Line Seeds, Inc.	96	O567 F1		
	Rijk Zwaan	97	Ellis		
		98	Hestan		
		99	Jerada		
	Seminis Vegetable Seeds	100	Caribou		
		101	Carlano		
		102	Carruba		
		103	Carvalo		
		104	Carvora		
	Sumika Agrotech Co., Ltd.	105	20MTV035C		
		106	20MTV036C		
		107	20MTV037C		
		108	11E082		
		109	11E083		
	Vilmorin	110	Bolero		
		111	Musico		
		112	Presto		
		113	Speedo		
Processing	Bejo Seeds, Inc.	114	Belgrado F1	Jumbo, Berlikum	
		115	Berlin F1	Jumbo, Berlikum	
		116	Baldio F1	Jumbo, Berlikum	
		117	Brava F1	Jumbo, Berlikum	
		118	Cupar F1	Jumbo, Chantenay	
		119	Canberra F1	Jumbo, Chantenay	
	Carosem GmbH	120	Bengala F1		
		121	Calindor F1 (CA 12447)		
		122	Cariana F1 (CA12329)		
		123	Calantis F1		
		124	CA D0133 F1		
	Gowan Seed Co.	125	Sumo		

Type/market	Company	Plot	Cultivar	Additional information from supplier	Notes
	Integra Hybrids, LLC	126	KXPC 564		
		127	WIC 502		
		128	WIC 503		
		129	WIC 504		
		130	WIC 506		
	Nunhems USA Inc.	131	Bull Dog		
	Pop Vriend Seeds B.V.	132	PV5550		
	Rijk Zwaan	133	Trafford		
		134	Warmia		
		135	Wolin		
	Seminis Vegetable Seeds	136	SV3118DH		
		137	SV5300DN		
	Vilmorin	138	Extremo	Dicer	
		139	Siroco	Slicer	
		140	Volcano	Slicer	
Colored	Bejo Seeds, Inc.	141	Mello Yello F1		
		142	Yellowstone F1		
		143	Deep Purple F1		
		144	Purple Haze F1		
		145	White Satin F1		
		146	Red Sun F1 (Bejo 3061)		
	Integra Hybrids, LLC	147	KXPC 588		
		148	KXPC 754		
	Nunhems USA Inc.	149	CreamPak		
		150	Purple Elite		
		151	Snow Man		
		152	RubyPak		
		153	YellowBunch		
	Seminis Vegetable Seeds	154	Malbec		
	Vilmorin	155	Gold Nugget		
	USDA ARS, Phil Simon	156	03'310-3	(5280 x 6366) x dY YELLOW	
		157	13'S364-1	R6636 RED	
		158	17'B103-1	P1129 PURPLE	
		159	17'B104-1	R6220 RED	
		160	17'B105-1	Y5654 YELLOW	
Others	Carosem	161	Caltona F1	Flakkee type	
		162	Calibra F1	Amsterdam type	
	Nunhems USA Inc. Inc.	163	Evora		
	Pure Line Seeds, Inc.	164	Aoflnant F1	Amsterdam	
		165	AO1OC4 F1	Amsterdam	
	Vilmorin	166	MVC 902	Yellow Kuroda	
Breeding		167	20-3778	Derived from Wisynth	
		168	20-3825	Derived from W281 and W285	

Type/market	Company	Plot	Cultivar	Additional information from supplier	Notes
	Univ. of Wisconsin, Irwin Goldman	169	2029	Derived from Wisynth and W279	
		170	2031	Derived from Wisynth, WAY274, W279	
		171	2032	Derived from Wisynth, W279	
		172	2036	Derived from Wisynth, W204C, W279	
		173	2132	Derived from W204C	
		174	2139	Derived from W285	
		175	2191	Derived from W281C, W285, W259, W280	
		176	2196	Derived from W281C, W259, W280	
		177	2197	Derived from W281C, W259, W280	
		178	2199	Derived from W281C, W285, W259, W280	
		179	2201	Derived from W281C, W259, W280	
		180	2207	Derived from W281C, W285, W259, W280	
		181	2216	Derived from W281C, W280, SAY273C, W259	
		182	2260	Derived from Dulcinea and WIOSC Danvers	
		183	2277	Derived from USDAL1408, W279, WIOSC Oranje	

40th International Carrot Conference: Field Tour, 30 August 2022

B. Organic Carrot Cultivar Demonstration



Location: Ralph’s Greenhouse, 16942 Calhoun Rd, Mount Vernon, WA 98273, USA (48.397112, -112.368552)
58 cultivars: 4 rows/cultivar with a 16-inch (25-cm) row spacing x 25 feet (7.6 m). Two low-density rows: ~400,000 seed/acre (1M seed/ha). Two high-density rows: ~1.5M seed/acre (3.75M seed/ha).
Planted: 29 April 2022 with a 4-row Jang planter. Seed placed 0.5 inches deep (1.25 cm). *One tropical cultivar (plot 23) planted on 17 May.*
Irrigation: Hand-lines (as needed).
Fertilizer: Compost and 4-4-2 chicken pellet organic fertilizer applied before planting.
Trial assistance: Jacob Slosberg and Tim Terpstra (Gowan Seed Co.); Ray de Vries, John Vanderwal, and farm crew (Ralph’s Greenhouse); Lindsey du Toit, Michael Derie, and Alex Batson (WSU).
Grower’s comments: *The difficult conditions this season are reflected in the trial but do not necessarily reflect the potential of the cultivars in the trial.* Spring 2022 was cold and wet. Crops are 3-4 weeks late in maturity. Farm labor also was an issue this year. The north end of the trial was weeded on time, but the south end was weeded when labor was available. Starting on 8 August, carrots were harvested from the farm’s crops.

40th International Carrot Conference:

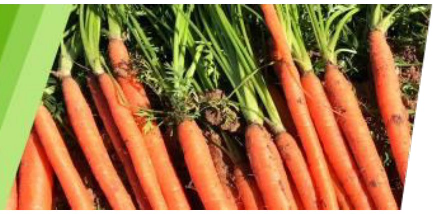
Organic cultivar demonstration planted at Ralph's Greenhouse, Skagit Co., WA, USA on 29 April 2022, except 1 tropical cultivar (plot 23) planted on 17 May.

Type/market	Company	Plot	Cultivar	Additional information	Notes
Imperator cellos	Nunhems USA Inc.	1	Maverick		
		2	Trophypak		
		3	Trooper		
	Pop Vriends Seeds B.V.	4	Jacinto (PV5041)		
	Rijk Zwaan	5	Ymer		
	USDA ARS, Phil Simon	6	19'B111-3	(B9304 × F7738) × Nb8524B	
		7	19'B113-3	(B6274 × F7737) × F5367B	
		8	19'B113-4	(2566 × F7737) × F5367B	
		9	17'788-3	(2126A × L3303B) × Npbw7261B	
		10	17'788-5	(5280A × Nbh2306B) × Npbw7261B	
Imperator cut 'n peel	Integra Hybrids, LLC	11	KXPC 520		
	Nunhems USA Inc.	12	HoneySnax		
		13	NUN 85938		
		14	SugarSnax		
	Pop Vriend Seeds B.V.	15	Olancha (PV 5304)		
		16	PV5311		
		17	PV5656		
	USDA ARS, Phil Simon	18	19'B112-3	(L1138 × L3303) × Nbh2306B	
		19	14'475-3	(7551 x 1131) x 9785	
		20	14'477-5	(9253 x 9788) x 9788	
		21	17'790-5	(L1406A × L0567B) × Nbh2306B	
		22	17'790-6	(L9793A × L3726B) × Nbh2306B	
Nantes	Agristar do Brazil Ltda	23	TES 19390	Tropical type, planted 18 d later	
	Bejo Seeds, Inc.	24	Naval	Cello, slicer, organic seed	
		25	Miami	Late Nantes, organic seed	
	Integra Hybrids, LLC	26	KXPC 044		
		27	WIC 203		
	Nunhems USA Inc.	28	Allyance		
		29	Romance		
	Organic Seed Alliance	30	Fantasia		
		31	Orange Flavor Pop'n		
		32	Orange Strain Pop'n		
		33	PYP Dark Pop'n		
		34	R6220		
		35	R6336		
		36	YEH1	2020 organic seed	
	Pop Vriend Seeds B.V.	37	Bryce (PV 5412)		
		38	PV5455		
		39	PV5457		

Type/market	Company	Plot	Cultivar	Additional information	Notes
	Rijk Zwaan	40	Jerada		
Processing	Bejo Seeds, Inc.	41	Cupar	Jumbo, Chantenay, organic seed	
	Carosem GmbH	42	Bengala F1		
	Gowan Seed Co.	43	Sumo		
	Integra Hybrids, LLC	44	WIC 506		
	Pop Vriend Seeds B.V.	45	PV 5550		
	Rijk Zwaan	46	Trafford		
Colored	Integra Hybrids, LLC	47	KXPC 754		
	Nunhems USA Inc. Inc.	48	CreamPak		
		49	Purple Elite		
		50	Snow Man		
		51	YellowBunch		
	USDA ARS, Phil Simon	52	03'310-3	(5280x6366) x dY YELLOW	
		53	13'S364-1	R6636 RED	
		54	17'B103-1	P1129 PURPLE	
		55	17'B104-1	R6220 RED	
		56	17'B105-1	Y5654 YELLOW	
Breeding	CANOVI (Univ. BC, Canada)	57	Red Nantes Breeding Pop 2021	UBC CANOVI breeding program	
		58	Orange Nantes Breeding Pop 2021		

Seminis

Grow better together



/// Vegetables by Bayer

Carrot Variety Highlights

SVDC2089

SVDC2089 is a cut and peel variety with excellent plant health, good root uniformity and eating quality which will provide a high yield to growers. This variety can be grown in all cut and peel carrot growing regions in United states, especially organic market where top health is very important. SVDC2089 has good tolerance to powdery mildew, a superior root with good length and uniformity. It's excellent texture and flavor, clean top and root length and uniformity make SVDC2089 a great option for growers.

SVDC1978

SVDC1978 has very good root shape and size uniformity in combination with good top attachment and plant vigor. Long roots with excellent tops makes SVDC1978 an attractive cut and peel carrot. With tolerance to powdery mildew and the combination of root quality and top vigor, growers will be rewarded with a high yield potential.

SVDC4193

SVDC4193 can be used in the cut and peel market throughout the US and Eastern Canada and may also be used as a slicer with reduced populations. This product offers high yield potential and great value to the customer. It has excellent root quality with long, smooth uniform roots that give growers a high-quality carrot with good yield potential. SVDC4193 has vigorous tops with a strong attachment and produces a high pack out at harvest.

YOUR GROWING ENVIRONMENT PROVIDES A WIDE RANGE OF CHALLENGES. WE'RE CONSTANTLY INNOVATING TO HELP YOU TO OVERCOME THOSE CHALLENGES SO THAT YOU CAN MAINTAIN A STEADY CUSTOMER BASE AND GROW YOUR BUSINESS. WE KNOW THAT WHEN WE CAN PARTNER WITH YOU TO HELP YOU PROVIDE PRODUCTS THAT LOOK AND TASTE DELICIOUS, WE ALL SUCCEED. BECAUSE WE'RE NOT JUST GROWING YOUR BOTTOM LINE. WE'RE GROWING THE HEALTH OF THE WORLD.

For more information, please contact us

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Exceptional tops combined with outstanding root quality yielding high pack-out rates.

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Vilmorin SEED GENERATION

Vilmorin is a brand from Vilmorin-Mikado