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CARROT IMPROVEMENT FOR ORGANIC AGRICULTURE WITH ADDED GROWER AND CONSUMER VALUE

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Abstract: Carrot Improvement for Organic Agriculture (CIOA) is a long-term breeding project started in 2011 to address 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. Organic growers require vegetable varieties that are adapted to organic growing conditions and hold market qualities demanded by the organic consumer including superior nutrition and exceptional flavor. In carrots, work has been done to identify and breed for nutritionally superior varieties across multiple color classes including orange, red, purple and yellow. These varieties are in high demand and in a high value crop, however much of this germplasm has not been improved for organic systems in general. The project also evaluated the performance of varieties in organic versus conventional systems during the first five years to assess the potential for breeding for organic soil conditions. Organic producers need varieties that germinate rapidly with good seedling vigor, compete with weeds, resist pests, are efficient at nutrient uptake and are broadly adapted to organic growing conditions. The CIOA project is ongoing, building off of research to date, with the goal of delivering improved carrot varieties; improved understanding of the farming systems influence (organic vs. conventional) on variety performance; and developing a breeding model adaptable to other crops for organic systems (Simon et. al, 2016). While significant progress has been made in carrot breeding to improve nutritional value, flavor, and disease resistance for conventional production systems, the majority of the conventional U.S. crop is threatened due to loss of chemical fumigants and sprays to control nematodes and Alternaria leaf blight, and organic production has no obvious means for economical carrot production when either of these pests threaten the crop.

Introduction:

Organic production of carrots presents several significant challenges from pests and diseases. Over 80% of the U.S. carrot production land is infested with one or more of the common species of root-knot nematodes. Alternaria leaf blight, other foliar diseases and cavity spot are major carrot diseases in virtually all production areas of the world. It is urgent and vital to the future of the US organic vegetable industry that effective non-chemical methods of nematode and leaf blight control be developed. Carrots are one of the slowest crops for growers to establish and grow. This often makes weed control the most expensive cost of organic carrot production. Flavor and nutritional value are the most important characteristics noted by consumers of organic foods. Among novel colored carrots are breeding stocks with some of the most vigorous growing seedlings and large tops. This project is developing novel carrots improved for nutrition and flavor, integrated with critical pest and disease resistance and vigorous growth. This project also expands our understanding of root-microbiome interactions critical for growth and nutrient uptake of organically-grown carrots.

Material and methods:

Cultivar development and release: All stages of the carrot breeding “pipeline” are advanced from initial screening of material to delivering finished cultivars. The primary activities are to: 1) complete breeding and release of new cultivars from advanced populations identified and developed in prior project research; 2) advance populations previously identified through centralized and decentralized participatory selection; 3) create new breeding populations by crossing germplasm that combines priority traits; and 4) screen additional diverse carrot germplasm from the USDA collection for suitability in organic production and increase promising populations. Variety trials are being conducted in multiple environments with diverse participants to accomplish several goals including: evaluation of breeding materials, engaging stakeholders, and reporting on performance of commercially available organic cultivars to support adoption of organic seed.

Understanding root microbiome interactions: Hoagland, is identifying carrot genotypes that can access key nutrients under limiting environments and avoid heavy metal uptake. Because AMF associations are critical to both accessing plant nutrients and helping plants mediate drought stress, the second study led by Silva, will focus on relationships among carrot genotypes and specific AMF species.

Utilizing molecular markers to improve nematode resistance: Research in this focus area utilizes molecular markers for nematode resistance to evaluate and select elite carrot populations led by Simon and Roberts. CIOA 1 released seven nematode resistant carrot populations and identified nematode resistance genes conferring resistance. CIOA2 builds upon this success by utilizing these molecular markers to confirm the identity of resistance genes segregating in breeding stocks derived from these sources and utilize those markers to select parental roots with resistance alleles from multiple genes to assure strong resistance during the breeding process.

Evaluating and improving carrot flavor: Assessment of carrot flavor, led by Dawson, is integrated into all germplasm evaluations and breeding activities as flavor is a priority trait necessary for the successful adoption of new cultivars with quality agronomic traits. Sensory analysis including flavor, texture and culinary quality is conducted on advanced materials harvested from replicated research station trials.

Results:

Variety development and release is underway with diverse breeding materials being grown at all national trial sites and seed increases of promising lines regenerated annually. Three new orange breeding populations have been created with a combination of flavor, enhanced carotene content, Alternaria and cavity spot resistance. Red, orange, yellow, and purple breeding populations have been created with a focus on flavor, texture and color. Purple, red and yellow open-pollinated varieties are soon to be released with testing underway at organic seed companies.

Research trials were held in Indiana, Wisconsin, Washington, and California and on-farm sites in Washington, Indiana, Hawaii, Maine, Virginia and Vermont. Included were 12 advanced breeding populations check varieties, plus selections from among an additional 34 potentially promising breeding populations that varied among trial sites. Evaluations included 3 seasonal top growth assessments and harvest yield and quality analysis, and post-harvest nutritional pigment and flavor analysis.

Carrot cultivars differed in response to water limitation according to cultivar-mycorrhizal species pairing. In addition to AMF, an abundant and diverse assortment of other microbial taxa that can help carrots acquire nitrogen and withstand biotic and abiotic stress also colonizes carrots. Microbes were identified within the seeds and taproots of a diverse set of carrot genotypes and demonstrated that they have potential to improve seedling establishment, help carrots acquire nitrogen and phosphorous, and withstand assault by *Alternaria dauci*, a key carrot pest. Microbial populations in carrot roots that are antagonistic to *A. dauci,* were greater in organic than conventional farming systems, demonstrating the value of greater soil health in organic systems (Abdelrazek et al, 2018).

Advanced experimental selections and additional potentially promising selections were included in field trialing for resistance to the most prevalent root-knot nematodes occurring in California. Selected carrots were advanced for seed production to be included in the genetic analysis, molecular marker evaluation, and breeding line development. Molecular marker evaluation underway has developed molecular markers for narrower genomic regions flanking the six major nematode resistance genes identified to date.

CIOA varieties were evaluated by chefs participating in vegetable flavor evaluations including three varieties slated for release. These varieties were also tasted by attendees at the international carrot conference in Madison, WI in August 2018 and multiple chef-public events including the Culinary Breeding Network Variety Showcases and University of Wisconsin Farm to Flavor showcase events. Taste evaluations by project personnel and participating chefs on orange, red and purple breeding lines as well as check varieties are anticipated in November, to provide quantitative and qualitative feedback on their culinary qualities. Evaluation of flavor, carotenoids and anthocyanins of all CIOA carrots is ongoing. Postharvest storage quality (rots, sprouting) is being noted.

Discussion:

Organic growers need vegetable varieties adapted to organic growing conditions with market qualities demanded by organic consumers. In carrots, weed competition, nutrient acquisition, nematodes, and disease pressure are particularly critical challenges to both fresh market carrots and carrot seed production, while flavor, appearance, and nutrition are key market qualities. This project is expanding diversity of improved carrot varieties for organic producers and consumers; improved understanding of cultivar performance in organic systems; improved understanding of how carrot genotypes interact with the root microbiome to access key nutrients under limiting environments and avoid heavy metal uptake; and a breeding model that may be adapted to other crops for organic cultivar development.

References:

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Disclosure of Interest: None Declared

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