Trial Report Brief: Orange Nantes Carrots 2023

Executive summary: This is the sixth year of the CANOVI orange Nantes carrot variety trials on farms across Canada, with it being the first year of including growers in the United States (US) (n = 44). Out of seven trialled varieties, “Bolero” F1 had the highest average score for every agronomic trait, with open-pollinated (OP) “CANOVI Orange” and “CIOA Orange Flavour” being second and third highest rated. Participants also voted these same varieties highest as the ones they would grow again. OP orange carrot varieties need continued breeding and selection to improve their overall agronomic performance, especially against F1 varieties and in different climates.

Background: The CANOVI orange Nantes carrot breeding project began in 2018, in response to BC grower interest in a sweet, deep orange, open pollinated Nantes variety that could be produced for both roots and seed in BC. The goal was to provide a viable replacement for workhorse hybrids like “Bolero” F1, in order to strengthen regional and Canadian seed security. This trial’s original and continued goal is to test the CANOVI orange Nantes carrot population alongside commercial hybrid (F1) and open-pollinated (OP) cultivars to gauge their readiness for commercialization. This year’s trial was delivered in collaboration with the Organic Seed Alliance (OSA) and Carrot Improvement for Organic Agriculture (CIOA) to offer a greater diversity of organically bred carrot lines and foster knowledge exchange across North America.

Varieties: We chose seven varieties of orange nantes carrots to evaluate. All the varieties we included in this study were open pollinated (OP), except “Bolero” F1 which acted as a check variety. Seeds of all varieties were grown in Canada or the US.

Results: Based on ANOVA analyses, variety had a significant effect on all agronomic traits. Region (East or West Canada, or the US) had a significant effect on all traits except canopy and flavour (Table 4 in the full report). Climate conditions also had variable significant effects on all agronomic traits except germination, flavour, and overall rating (Table 6 in the full report). “CANOVI Orange” had the highest rated scores among OP varieties.

Participants most commonly voted “Bolero” (88%), “CANOVI Orange” (85%), and “CIOA Orange Flavor” (75%) as the varieties they would grow again.

Average ratings for agronomic traits across varieties.

Variety	Germination ***	Vigor ***	Canopy ***	Yield ***	Uniformity ***	Marketability ***	Appearance ***	Flavour *	Overall ***
Bolero	4.3a	4.4a	4.3a	4.4a	4.2a	4.3a	4.2a	4.0a	4.2a
CANOVI Orange	3.8b	3.8b	3.9ab	3.8b	3.6b	3.7b	3.9ab	3.8ab	3.8b
CIOA Orange Flavour	3.4bc	3.7b	3.6bcd	3.3cd	3.6b	3.8b	3.8ab	3.9ab	3.6bc
CIOA Orange Strain Cross	3.5b	3.7b	3.8abc	3.5bc	3.6b	3.9b	3.9ab	3.5ab	3.7b
Touchon	2.9cd	3.2c	3.4cde	2.9de	3.3bc	3.6bc	3.7bc	3.7ab	3.3cd
Dulcinea	2.8d	2.9c	3.2de	2.7ef	3.1cd	3.2cd	3.4cd	3.8bc	3.0de
Uberlandia	2.5d	2.8c	3.1e	2.3f	2.9d	2.8d	3.1d	3.2c	2.7e

Darker green colour = higher score, yellow colour = lower score; The asterisks indicate the significant level of the impact of variety: *** p<0.001, ** p<0.01, * p<0.05; Different letters indicate the significant difference of ratings in the same column.

Takeaways and next steps: Although “Bolero” F1 outperformed all OP carrot varieties included in this trial, runner-up OP “CANOVI Orange,” “CIOA Orange Flavor,” and “CIOA Orange Strain Cross” were still highly beloved by growers. Interestingly, all the collaboratively-bred OP carrot varieties outperformed all the OP carrot varieties from commercial seed companies.

Germination and yield were the agronomic characteristics that ranged the most across carrot varieties, highlighting areas of improvement for targeted improvement for both breeders and growers. Continued breeding and selections can be done to improve the agronomic performance of OP carrot varieties, especially against F1 varieties and in different climates. Seed growers in these trials develop more skills and experience in the variety development process that can increase the overall quality of the seed varieties they produce. These trials also create a positive feedback loop in the variety development process that strengthens organic seed production systems.

We encourage participants to access SeedLinked to review which carrot varieties worked best for them in their specific regional climate and farming systems.

More results can be found in full report below

Trial data analysis and report by Weijia Wang and Chris Thoreau (UBC Farm), and Michelle Dang (SeedChange). For more information, please visit seedsecurity.ca/en or email weijia.wang@botany.ubc.ca

Full Trial Report: Orange Nantes Carrots 2023

Participants and Locations

This study included 89 participants across Canada and the United States (US) (Figure 1) with 50 marked as completed (39 participants in Canada and 11 in the US) on Seedlinked (56% completion). We removed six of the completed trials (five from Canada and one from the US) from data analysis due to missing or questionable data; therefore, 34 Canadian trials and 10 US trials (n_{total} = 44) were used in the data analysis. The University of British Columbia (UBC) Organic Farm acted as the "mother site" of this trial, as researchers there sowed triplicate plots of each variety for observation.

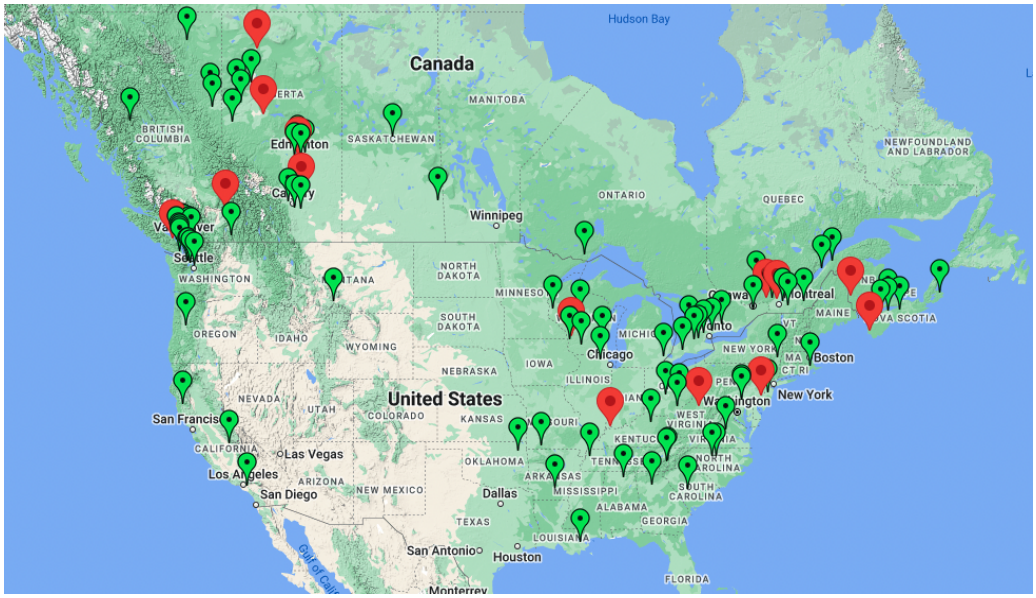

Figure 1. Geographical spread of CANOVI orange carrot participants across Canada and the United States. Each location mark is a participant accepted to the trial. Green mark indicates active trials and red indicates inactive trials.

Carrot Varieties

Table 1 shows the full list of the carrot varieties we selected for this study and their seed sources.

Table 1. Overview of the agronomic and breeding history of orange nantes carrots varieties included in this study. Days to Maturity are listed as "N/A" (not available) for the CANOVI and Organic Seed Alliance (OSA) varieties, as they have not been defined yet.

Variety/Breeding Line	OP / F1 / Breeding Line	Days to Maturity	Breeder	Seed Source
CIOA Orange Flavour Select	OP	N/A	CIOA	CIOA
CIOA Orange Strain Cross	OP	N/A	CIOA	CIOA
Uberlandia Flavor	OP	N/A	CIOA	CIOA
CANOVI Orange (2021 Selections)	Breeding Line	N/A	CANOVI	CANOVI

Dulcinea	OP	60	Fruition Seeds	Fruition Seeds
Touchon Deluxe	OP	65-70	Heirloom	BC Eco Seed Coop
Bolero F1	F1	75	Vilmorin	Johnny's Selected Seeds

Planting

We asked participants to plant 12 linear feet of carrots per variety at approximately 1" spacing after thinning, using single or multiple rows per bed. Seeds were sown in June or early July for harvest in September to October. Participants used their usual organic methods for soil fertility and weed management.

Evaluation

Participants evaluated varieties using the desktop or mobile SeedLinked app for germination, vigour, canopy closure, yield, uniformity, marketability, appearance, flavour, and overall performance on a scale of 1 (low) to 5 (high). We provided a rubric that defined the rating scale for each trait. Further planting and evaluation details are available in the 2023 Carrot Trial Protocol.

Analysis

Evaluation summaries were available on the SeedLinked website immediately after trial closure. In addition, CANOVI researchers performed statistical analysis and presented results in this trial report.

Would you grow this again?

We asked participants which carrots varieties they would grow again, with a summary of results available in Figure 2. Overall, participants most commonly voted "Bolero" (88%), "CANOVI Orange" (85%), and "CIOA Orange Flavor" (75%) as the varieties they would grow again.

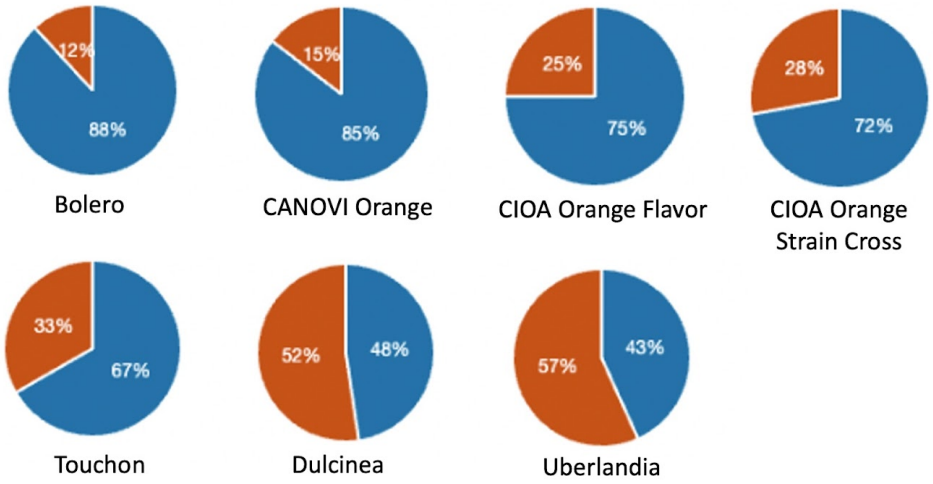

Figure 2. Percentage of participants who voted to grow a carrot variety again. Red depicts the percentage of participants who would **not** grow a variety again, while blue depicts that percentage of participants who would grow a variety again.

Distribution of “Overall Performance” Rating by Varieties

We asked all participants to rate the overall performance of varieties from 1 (low) - 5 (high). Figure 3 depicts the ratings for overall variety performance. The hybrid variety “Bolero” used as a control for comparison had best overall performance with the rating data points distributed mainly around 4 or 5 among all growers. The “CIOA Orange Flavour,” “CIOA Orange Strain Cross,” and “CANOVI Orange” had better overall performance than the other OP varieties, with rating data points distributed mainly in the 3-5 range. The variety “Touchon” had overall ratings distributed mainly in the 3-4 range. Varieties with widely distributed data points in the 1-5 range, like “Dulcinea” and “Uberlandia” showed variable agronomic performance across farms.

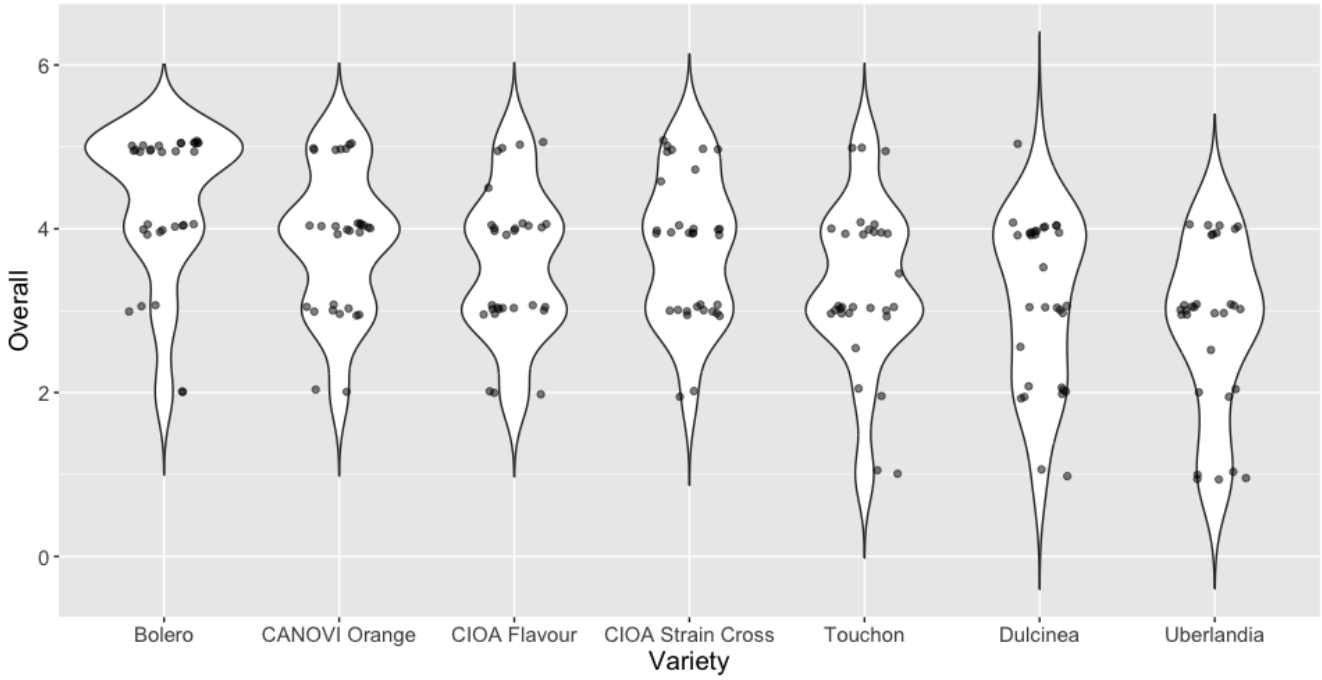

Figure 3. Distribution of overall performance ratings (1-5) of carrot varieties across participants. Dots on the bars represent individual ratings.

Effect of Variety and Region on Agronomic Traits

Analysis of variance (ANOVA) analysis indicated that variety had a significant impact in the different results of all rated agronomic traits. Variety has a significant effect on all agronomic traits.

Researchers grouped participants into three different growing regions which were Eastern Canada (n = 14, Canadian provinces east of Manitoba), Western Canada (n = 20, Canadian provinces west of Manitoba), and the US (n = 10, all states in the US). Region had a significant effect on germination, yield, uniformity, and overall performance. Despite these significant effects, region and variety did not interact to produce a significant effect for any agronomic traits; this means that specific varieties did not perform significantly differently in one region versus another (Table 2).

Table 2. Summary of ANOVA analyses on the effect of variety, region, and their interaction on the agronomic performance of carrot varieties. Region includes Eastern Canada, Western Canada, and the US.

Variable	Germination	Vigour	Canopy	Yield	Uniformity	Marketability	Appearance	Flavour	Overall
Variety	***	***	***	***	***	***	***	*	***
Region	***	*	-	**	**	*	*	-	**
Variety x Region	-	-	-	-	-	-	-	-	-

Significant level: p-value <0.001***, <0.01**, p-value < 0.05 *, no significance "-".

The agronomic performance of each variety is listed in Table 3. Participants rated "Bolero" the highest for all agronomic traits across all varieties. "CANOVI Orange" performed the best among open pollinated varieties for most agronomic traits. "Uberlandia" performed the worst among varieties with lowest rating scores in all traits.

Table 3. Average ratings (1-5) for agronomic traits across carrot varieties.

Variety	Germination ***	Vigor ***	Canopy ***	Yield ***	Uniformity ***	Marketability ***	Appearance ***	Flavour *	Overall ***
Bolero	4.3a	4.4a	4.3a	4.4a	4.2a	4.3a	4.2a	4.0a	4.2a
CANOVI Orange	3.8b	3.8b	3.9ab	3.8b	3.6b	3.7b	3.9ab	3.8ab	3.8b
CIOA Orange Flavour	3.4bc	3.7b	3.6bcd	3.3cd	3.6b	3.8b	3.8ab	3.9ab	3.6bc
CIOA Orange Strain Cross	3.5b	3.7b	3.8abc	3.5bc	3.6b	3.9b	3.9ab	3.5ab	3.7b
Touchon	2.9cd	3.2c	3.4cde	2.9de	3.3bc	3.6bc	3.7bc	3.7ab	3.3cd
Dulcinea	2.8d	2.9c	3.2de	2.7ef	3.1cd	3.2cd	3.4cd	3.8bc	3.0de
Uberlandia	2.5d	2.8c	3.1e	2.3f	2.9d	2.8d	3.1d	3.2c	2.7e

1. The asterisks indicate the significant level of the impact of variety: *** p<0.001, ** p<0.01, * p<0.05.
2. Darker green colour = higher score, yellow colour = lower score.
3. Different letters indicate the significant difference of ratings in the same column according to LSD (least significant difference) analysis.

The average agronomic performance of all varieties by region is listed in Table 4. Carrots grown in West Canada scored significantly higher than carrots grown in East Canada or US.

Table 4. Average ratings of agronomic traits by region.

Region	Germination ***	Vigour *	Canopy -	Yield **	Uniformity **	Marketability *	Appearance *	Flavour -	Overall **
East Canada	3.2b	3.3b	3.5a	3.2ab	3.2b	3.5b	3.6b	3.6ab	3.3b
West Canada	3.6a	3.7a	3.7a	3.5a	3.7a	3.8a	3.9a	3.8a	3.7a
US	3.0b	3.4ab	3.5a	2.9b	3.5ab	3.5ab	3.6ab	3.5b	3.3b

1. The asterisks indicate the significant level of the impact of variety: *** p<0.001, ** p<0.01, * p<0.05.
2. Darker green colour = higher score, yellow colour = lower score.
3. Different letters indicate the significant difference of ratings in the same column according to LSD (least significant difference) analysis.

Effect of Climate on Agronomic Traits

Among the 44 completed trials, 30 trials had accompanying climate data. Seedlinked grouped these trials into different climate types, including average climate (n = 13), drought (n = 11) and excessive rain (n = 6).

Researchers conducted ANOVA analysis on the subset data of climate information to test the effect of variety, climate, and their interaction. The results indicated that climate had a significant effect on several agronomic traits, especially in vigour, uniformity and marketability. The interaction between variety and climate only had a significant effect on yield (Table 5).

Table 5. Summary of ANOVA analyses on the effect of variety, climate, and their interaction on the agronomic performance of selected trials. Climate data was split up by average climate, drought or excessive rain.

Variable	Germination	Vigour	Canopy	Yield	Uniformity	Marketability	Appearance	Flavour	Overall
Variety	***	***	**	***	***	***	***	**	***
Climate	-	**	*	*	***	**	*	-	-
Variety x Climate	-	-	-	*	-	-	-	-	-

Significant level: p-value <0.001***, <0.01**, p-value < 0.05 *, no significance "-".

The average ratings of agronomic traits across climate conditions are presented in Table 6. Excessive rain climates resulted in lower ratings for vigour, canopy closure, yield, uniformity, marketability and appearance.

Table 6. Average ratings of agronomic traits by climate.

Climate	Germination -	Vigour **	Canopy *	Yield *	Uniformity ***	Marketability **	Appearance *	Flavour -	Overall -
Average	3.4a	3.6a	3.6a	3.4a	3.7a	3.6a	3.8a	3.7a	3.6a
Drought	3.3ab	3.7a	3.6a	3.2ab	3.4a	3.6a	3.7ab	3.7a	3.5ab
Excessive rain	2.9b	2.9b	3.1b	2.9b	2.8b	3.0b	3.3b	3.6a	3.2b

1. The asterisks indicate the significant level of the impact of region: *** p<0.001, ** p<0.01, * p<0.05, - not significant;
2. Darker green colour = higher score, yellow colour = lower score;
3. Different letters indicate the significant difference of ratings in the same column according to LSD (least significant difference) analysis.

UBC Organic Farm Mother Site

The climatic conditions at the UBC mother site is shown in Figure 4. The daily average temperature and precipitation was recorded from June 27, 2023, which was the day carrot seeds were sown, to September 28, 2023, which was the day the carrots were harvested. The graph shows the average daily temperature at the mother site. Researchers irrigated plots when needed.

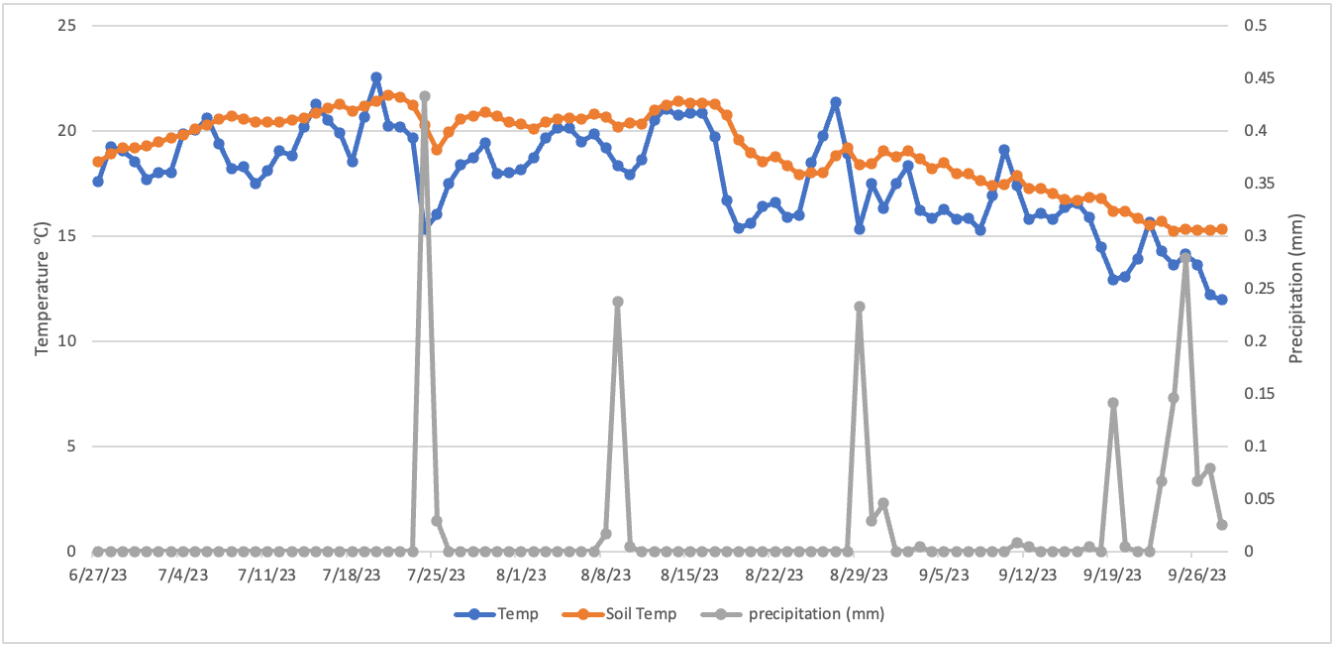

Figure 4. Daily average temperature (℃), soil temperature (℃), and precipitation (mm) at UBC Organic Farm of each day during the carrot growing season.

At the UBC mother site, researchers planted three replicated plots for each variety. Researchers rated each plot for germination (on July 20), vigour (August 8), and canopy closure with the scale of 1-5. Researchers rated canopy closure two times observationally on August 15 and August 23, and one time on August 23 using the "Canopeo" App to obtain the percentage of leaf coverage in each plot. On September 29, a researcher rated the roots of each variety in each plot for uniformity, marketability, appearance, flavour, and overall performance. Two researchers combined roots from all three plots and evaluated them for flavour. The average rating of all replicates for each variety is presented in Table 7.

Table 7. Average ratings for agronomic traits across varieties at UBC Organic Farm. Ratings were the average of the three replicates and the two canopy assessments. "DAP" means "days after planting."

Variety	Germination	Vigour	Canopy 49 DAP	Canopy 57 DAP	Canopy Percentage	Uniformity	Marketability	Appearance	Flavour	Overall
Bolero	4.3	5.0	4.7	4.8	69.3%	3.8	3.8	3.8	4.0	3.8
CANOVI Orange	3.7	4.7	4.2	4.2	56.0%	3.5	3.7	3.7	3.0	4.0
CIOA Orange Flavour	2.3	4.5	4.0	4.2	54.0%	4.2	4.2	3.8	3.0	4.0

CIOA Orange Strain Cross	2.0	4.5	4.2	4.5	58.3%	3.8	4.3	4.2	4.3	3.8
Dulcinea	2.0	3.2	3.3	3.3	40.3%	3.7	3.2	4.0	4.5	3.8
Touchon	1.3	3.0	2.7	3.2	43.7%	3.8	3.3	3.5	3.0	3.5
Uberlandia	1.3	3.7	3.3	3.2	36.7%	4.2	3.5	2.7	3.8	1.7

1. Darker green colour = higher score, yellow colour = lower score

At the UBC mother site, the varieties were not rated for yield using the 1-5 scale; instead, the roots were counted as total root count and marketable root count, and the counted roots were weighed. Table 8 shows these measures as an average across replicates. The varieties “Bolero,” “CANOVI Orange," and “CIOA Orange Strain Cross” had more marketable (>30) roots than the other types; however, the percentage of marketable roots (number of marketable roots / number of total roots) of all varieties were about 80-85%, except “Uberlandia” which only had 42% marketable roots.

Table 8. Average root counts and root weights (lb) of each carrot variety at UBC Farm.

Variety	Root Count		Root Weight (lb)		Percent Marketable Root
	Total	Marketable	Total	Marketable	
Bolero	40	34	12.73	11.00	84.9%
CANOVI Orange	35	30	9.76	8.94	85.6%
CIOA Orange Flavour	26	21	10.47	8.43	79.7%
CIOA Orange Strain Cross	37	30	13.30	11.40	80.9%
Dulcinea	27	22	8.30	4.83	81.3%
Touchon	18	15	8.38	6.71	81.8%
Uberlandia	17	7	4.63	2.42	42.0%

Supplemental Materials

Correlation of Agronomic Characteristics

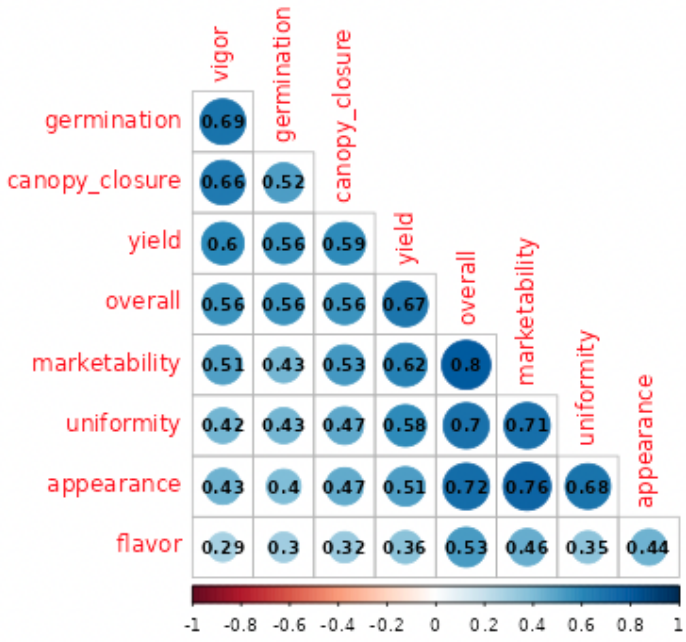

Figure 5. Correlation matrix between agronomic traits. Darker colours indicate a higher correlation between any two traits and the r-values (on each dot) indicate the strength (higher the stronger) and directionality (positive vs. negative) of the correlation.

Carrot Tasting Results

Carrot tasting was conducted at the Feast at Fields event on September 9, 2023. A total of 22 attendees tasted "CANOVI Orange" carrots and rated it on appearance, texture, and flavour on a scale of 1-5 (low - high) (Table 9).

Table 9. Average ratings of "CANOVI Orange" carrots by attendees at Feast at Fields.

Variety	Appearance	Texture	Flavour
CANOVI Orange	4.62	4.62	4.59

Another carrot tasting was conducted at UBC Organic Farm on September 16, 2023. A total of 61 participants tasted and rated "CANOVI Orange" for appearance, texture, and flavour with the same 1-5 scale (Table 10).

Table 10. Average ratings of "CANOVI Orange" by participants at UBC Organic Farm on September 16, 2023.

Variety	Appearance	Texture	Flavour
CANOVI Orange	4.40	4.37	4.29

University of Toronto Scarborough (UTSC) Ontario Mother site

At the Ontario mother site at UTSC, researchers grew two replicates of each specialty carrot variety. Researchers rated each replicate for all agronomic traits on the scale of 1-5. The site reported excessive rain at the establishment period which could have affected germination. The site also reported that the uniformity was abnormally poor and could be due to tilling practices.

Table 11. Average ratings for agronomic traits across varieties at Ontario Mother Site Farm (Is there a name for the farm?). Ratings were the average of the two replicates. "NA" denotes missing data.

Variety	Germination	Vigour	Canopy	Yield	Uniformity	Marketability	Appearance	Flavour	Overall
Bolero	5	4	5	4	3.5	3.5	3.5	4	3.5
CANOVI Orange	3	4	4	3	3	2	2	4	3
CIOA Orange Flavour	3.5	4	5	3.5	2	2	2	3	2.5
CIOA Orange Strain Cross	3	NA	4	4	3	2	2	3.5	2.5
Dulcinea	3	2	3	3	2	1.5	2	3.5	2.5
Touchon	3	3	4	3	2.5	2	2	5	3
Uberlandia	1.5	NA	3	1.5	1	1	1	1	1

Darker green colour = higher score, yellow colour = lower score