I-148 Expanding the potential for carrot production in BC: Processing and organics

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EXECUTIVE SUMMARY

Carrots production in Canada is not currently meeting local demand. Carrot growers have a plethora of choices when it comes to carrot variety selection. There is currently no mechanism in place for conducting third-party evaluations for both new and commercially available varieties. The objective of this study was to conduct a carrot variety trial with a focus on organic production. Two demonstration field plots were planted in the 2013 field season, one was a large scale planting at a conventionally managed site and the other was a small scale planting at an organically managed site. Varieties were compared within sites and not between sites, because of the many differences in production. We tested 14 varieties at the conventional site and 12 at the organic site. There were three numbered varieties, five coloured varieties and a mixture or Imperator, Berlicum Nantes, Danvers and Nantes type of carrots. Parameters such as germination (in a Petri dish assay), early season stand, foliar disease, insect damage on roots, yield, marketable roots were evaluated at both sites. Additionally, taste, appearance and buyer comments on each variety were obtained from two buyers for BC Fresh and a buyer for Discovery organics. Carrots were then stored for 4 weeks and the impact of storage on flavor and on quality of tops was assessed. Varieties that performed well across a number of our assessment parameters were Purple Snax, Cream Pak, Yellow Pak, White Satin, Fidra, 85180, Mokum and Jeanette. Because of the demonstration nature of our trials, in particular lack of replication at each site and uneven crop growth at the organic site, we cannot draw firm conclusions on variety performance. Moving forward, variety trial work for carrots should follow a strong protocol that produces reliable findings. However, trials are most valuable when they are conducted in collaboration with growers in production fields. So the challenge for the industry will be to balance these needs in order to continue variety trial testing that will result in useful information for growers.

INTRODUCTION AND OBJECTIVES

In 2010, Canada imported approximately 1000% more organic carrots than it produced (Vitins 2011), and local demand for organic carrots currently exceeds local supply (M. Driediger, personal communication, BC Fresh). Weed and pest control are difficulties that growers have in organic carrot production, regardless of scale. For example, the labour costs associated with weed control in a single organic carrot field (30 acres) on a Fraser Valley farm resulted in no net benefit compared to conventional production (K. Sihota, personal communication, Canadian Farms Inc.). Additionally, the assortment of carrot products consumed - from fresh market clip top or bunched carrots to processed baby carrots and juicing carrots - means that growers have to make complex choices in terms of the varieties that they grow.

To our knowledge there is no organized third party program for variety trials of vegetables in BC, except for potatoes. This lack of varietal testing puts BC growers at a disadvantage; variety selection is a decision that can profoundly impact subsequent returns (Williams and Roberts 2002). Yet despite the importance of varietal choice, fewer public resources are being put towards variety trial work across North America (Williams and Roberts 2002). Regular third party evaluations for carrots take place in the arid Columbia Basin area of Washington State (Keller, 2008). The University of Saskatchewan has been conducting carrot variety trials for the past 20 years (see Carrot Variety Trials Searchable Database http://www.usask.ca/agriculture/plantsci/vegetable/database/carrot.htm). However, varietal performance in these regions and growing practices will not necessarily be the same in BC. Further, varietal selection specifically for organic production is perhaps more challenging, as the goals and philosophies of organic agriculture require seed to be produced organically, be open pollinated, and breed in a manner that maintains species integrity (see Chable *et al*. 2008). In practice, organic growers have access to very few seed choices that are certified organic; but are allowed to use conventionally produced seed that is not treated. Thus growers have a number of choices and the challenge is to determine which varieties will work best for individual grower needs and planting conditions. The objective of this study was to conduct a carrot variety trial and to specifically evaluate the potential of varieties for organic production.

METHODS

Planting and maintenance

2012 - A carrot variety trial was planted on July 20, 2012 in Abbotsford, BC. The trial area was located in two beds along the North edge of the field, where there was a hedgerow of shrubs and trees. The trial area was divided into six blocks to account for differences in pest pressure and microclimate. The trial consisted of 17 varieties of carrots (Appendix 1), including industry standard Enterprise (Imperator) and Bolero (Nantes). Carrots were planted in 2-m long plots with three rows/plot and 6 plots/variety for a total of 144 plots. Plots were 0.5 m apart. Varieties were randomly assigned to plots with each variety in each block for a randomized block design (see Appendix 1). To ensure even crop spacing and to make planting more efficient, seeds were attached to seed tape at 20-cm intervals, using toilet paper and paste (Holdsworth 2013). A thunderstorm within 4 hours of planting ensured that plots were well watered. The field

was originally intended to be transitional to organics, but the grower decided to do conventional production instead. Adjacent carrot beds were sprayed with herbicide two weeks after planting the variety trial. Emergence in the variety trial area was poor, and we observed dead seedlings and patchy emergence throughout the trial area. We started to irrigate plots on August 2, 2012, with soaker house, with plots irrigated every two days for 1 hour. However, emergence continued to be poor and uneven throughout the plot area. We discontinued irrigation on August 20, 2012 following a rainstorm. Because of the poor growth in the trial area we discontinued this trial on September 20, 2012.

2013 - Two carrot variety trials were planted in 2013. The first trial was planted on June 5, 2013 in a conventional carrot field in Abbotsford, BC and consisted of 14 varieties (Table 1). The trial area was located in two rows, seven rows in from the North edge of the field. The field site was prepared into raised beds by the grower. The variety trial area was planted by the grower using a singular air seeder, and the trial consisted of one plot for each variety. Each plot was three rows wide and plot length varied from 30-m to 90-m (Appendix 1). The five coloured varieties (Table 1) were planted with a single coloured variety per row + an orange variety (Appendix 1). The grower suggested that this would allow them to harvest coloured varieties together for a mixed colour combination. All other plots were planted with a single variety/plot. The trial area was maintained by the grower using standard practices for irrigation and conventional carrot production including fungicide, insecticide and herbicide applications. Carrots were harvested on September 7, 2013.

Table 1. Description of carrot varieties planted at the conventional site in Abbotsford, BC.

Variety	**Description**	**Fungicide treated or untreated seed**
3302	Berlicum Nantes/Orange	Treated
85180	Jumbo Hybrid/Orange	Treated
85190	Jumbo Hybrid/Orange	Treated
Cream Pak	Imperator/Pale Yellow	Untreated
Fidra	Berlicum Nantes/Orange	Treated
Laguna	Imperator/Orange	Untreated
NutriRed	Imperator/Orange	Untreated
Propeel	Commercially available Imperator/Orange	Treated
Purple Snax	Imperator/Purple with orange core	Untreated
Sherbert	Imperator/Pale Orange	Untreated
Slender Cut	Commercially available Imperator/Orange	Treated
Sugar Snax	Commercially available Imperator X Nantes/Orange	Treated
Texto	Berlicum Nantes/Orange	Treated
Yellow Pak	Imperator/Pale Yellow	Untreated

The second trial was planted on July 5, 2013 in an organic field in Chilliwack BC and consisted of 12 varieties, seven of which were also planted in the conventional field and five of which were unique to the organic trial (Table 2). The trial area was recently cultivated and had previously been in cover crop/weeds. The planting area was not worked into raised beds and the plots were planted with a six-row manual seeder that was adjusted for the standard planting depth the grower used. Plots were 1 to 4-m long depending on the amount of seed available (Appendix 1). There were two plots each for eight of the varieties and only a single plot for the remaining four varieties (Table 2). After planting, the trial area was irrigated and covered with floating row cover (Agryl P30). The trial area was irrigated as needed by the grower and row cover was removed on July 25 so that plots could be weeded. At this time germination was patchy and irrigation was increased to daily. Heavy weed pressure throughout the trial area required approximately 80 hours of hand weeding over the course of August to mid-September. In order to reduce weed pressure straw mulch was laid down over the trial area on September 16 (Fig. 1). Carrots were harvested on October 18, 2013.

Figure 1. Organic carrot variety trial plots at a co-operating organic mixed vegetable farm in Chilliwack, BC. Picture taken September 30, 2013, after plots were weeded and mulched with straw. (Photo: R. Prasad).

Table 2. Description of carrot varieties planted at the organic site in Chilliwack, BC. All seed used was untreated.

Variety	**Description**
Sherbert	Imperator/Pale Orange
Laguna	Imperator/Orange
Yellow Pak	Imperator/Yellow
Purple Snax	Imperator/Purple with orange core
Cream Pak	Imperator/Pale Yellow
Napoli	Imperator/Orange – recommended for late season
NutriRed	Imperator/Red
Mokum	Imperator/Orange
Jeanette	Nantes/Orange
Sugar Snax	Imperator/Orange
Fly Away	Nantes/Orange – carrot rust fly resistance
White Satin	Danvers/White

Assessment Parameters

The 2013 trials were conducted as demonstration studies, i.e. no or little replication of treatments (varieties) in fields, uneven plot sizes, no industry standard or Control variety planted within test varieties (see Williams and Roberts 2002 for recommended criteria for variety trials). One of the challenges of not doing on-farm variety trial work is to develop collaborative relationships with growers, who understand the value of experimental design. For this trial experimental rigor was sacrificed in order to build relationships among growers and researchers. For the conventional trial we collected similar types of assessment data from the adjacent carrot beds planted by the grower (var. Enterprise). Thus we could compare the performance of each variety to the grower standard. For the organic field we were not able to do this, as the grower's carrots were planted several weeks earlier and were close to harvest before the variety trial carrot had started to mature. Thus for the organic trial, we primarily compared the performance of varieties to each other. Because of heavy weed pressure throughout the organic trial we only harvested out of the best plot when we had two plots/variety (Appendix 1).

Germination - A germination bioassay was conducted by placing 25 seeds of each variety into a 15-cm diameter Petri dish with moist paper towel for 96 hours at 22^{o}C. The number of seeds germinated was counted.

Early season stand and damping off - Early season stand counts were conducted on July 5 for the conventional field. We did not do a stand count on the organic plots because of uneven germination as a result of the heavy weed competition. Early stand counts consisted of counting the number of live and dead/poor vigor plants in three randomly placed 1-m long X 1 row wide transects/plot. Dead and poor vigour was attributed to damping off, which is common for carrots when they are planted in wet weather (Pscheidt and Ocamb 2013). For the largest plot (85190), we did an additional

three transects for a total of six transects. We also did early stand counts on the adjacent carrot beds belonging to the grower.

Foliar Disease, Insect, Yield and Quality - On the day of harvest we assessed top growth for signs and symptoms of foliar disease. Specifically, foliage and stems were assessed for foliar blight (Cercospora leaf spot and Alternaria leaf blight), powdery mildew and other symptoms. At the conventional site foliar disease was assessed in three randomly placed 1-m long X 1 row wide transects/plot. Disease was assessed along a single row/plot, and where a single variety was planted/plot we assessed in the middle row. For each of the three transects, the amount of foliage (including stems) with symptoms was estimated (% diseased material). For the organic site we assessed foliar disease along a single 1-m long X 1 row wide transect/plot.

Carrots were then harvested along the same 1-m long X 1 row wide transect where foliar disease was assessed. At the conventional site we harvested carrots along two transects/plot and at the organic site we harvested carrots along a single transect/plot. Carrots were examined for any diseases of the tap root (e.g. cavity spot and root knot nematode galls) and for carrot rust fly feeding damage. At the organic site we also saw evidence of wireworm feeding and so collected information on this pest as well. Carrots were then counted and graded into marketable and unmarketable roots. The reasons roots were unmarketable was also quantified, e.g. forking, splits, feeding damage, undersized. At the organic site we also assessed qualitatively the condition of the top growth and the ease of manually harvesting the carrot, as this is a criteria for carrot quality for both growers (B. Campbell, personal communication, West Coast Seeds) and buyers (S. Mise, personal communication, Discovery Organics). All of the carrots harvested/plot were weighed and the length of 10 marketable tap roots was measured. For the conventional site, carrots were weighed without tops and at the organic site carrots were weighed with tops.

Carrots were also evaluated by buyers for quality. The conventional carrots were evaluated by Randy Sihota and Aly Arounnothai (Canadian Farms Produce, Inc.), who are buyers and processors for BC Fresh. Organic carrots were evaluated by Stefan Mise, buyer for Discovery Organics. Each buyer assessed the varieties qualitatively for the following criteria - overall appearance, flavour, suitability of the variety for fresh market or processing, and other comments. Carrots were washed, topped (conventional), and only marketable roots were presented to buyers.

Post-harvest storage and assessment - Carrots from both the organic and conventional site were stored for four weeks at 4^{o}C and 90%RH and then evaluated for flavour and overall condition. In the case of the varieties tested at the organic site, the condition of the foliage after 21 days of storage was also assessed and then carrots were put back in storage for an additional week. Prior to storage, carrots from the conventional site were washed to remove any soil and surface debris and then dunked in a 0.5% bleach solution for 5 seconds (B. Wisbey, personal communication, Wisbey Farms), towel dried and placed in plastic totes and covered loosely with plastic sheets. Carrots from the organic site were washed carefully to avoid damaging roots; the intact carrots (roots and foliage)

were placed in a plastic bag and into storage. After removal from storage we qualitatively assessed the condition of carrots as well as taste. Taste was assessed by two individuals who sampled a 1-cm piece taken from the tip (A. Arounnothai, personal communication, Canadian Farms Produce Inc.) of carrots prior to storage and after four weeks in storage. The overall ranking and comments were compiled. For the carrots from the organic site we also determined the amount of foliage (percentage) that had turned yellow or brown and would require removal before the carrots could be sold.

RESULTS AND DISCUSSION

Germination Assay - Germination counts ranged from 70 to 95% (Table 3), and were within the ranges indicated by seed companies for the various seeds based on age and source. All seeds had been stored at room temperature (21^{o}C) and ambient relative humidity for three months prior to germination assay. Thus low germination rates for some varieties more likely reflect the effect of storage rather than seed quality. However, germination rates in this assay can help to explain some of the results in the field, e.g. early season stand.

Table 3. Germination assay results, percentage of seeds germinating out of 25 placed on Petri dish.

Variety	**% Germination**	**Variety**	**% Germination**
Laguna	62%	Yellow Pak	95%
3302	70%	Cream Pak	92%
85190	79%	Texto	83%
85180	67%	Fidra	88%
Sherbert	80%	Napoli	76%
Jeanette	75%	Propeel	79%
White Satin	91%	Sugar Snax	91%
Fly Away	88%	Slendercut	80%
NutriRed	91%	Purple Snax	91%
Mokum	90%		

Early season stand - In terms of early season stand establishment, Purple Snax, Yellow Pak and 3302 all had higher seedling stands than the industry standard variety growing in adjacent beds (Fig. 2). While Purple Snax and Yellow Pak also had high germination rates, 3302 did not (Table 4). This suggests that germination rates for 3302 may again reflect response to storage conditions rather than seed quality. We also observed dead or severely wilted seedlings in every variety in the variety trial and in the grower's beds, although symptoms were patchily distributed. Diagnostic lab results came back negative for biotic causes of the symptoms and abiotic causes were suspected (V. Joshi, BC Ministry of Agriculture, Plant Diagnostic Lab Report 9801).

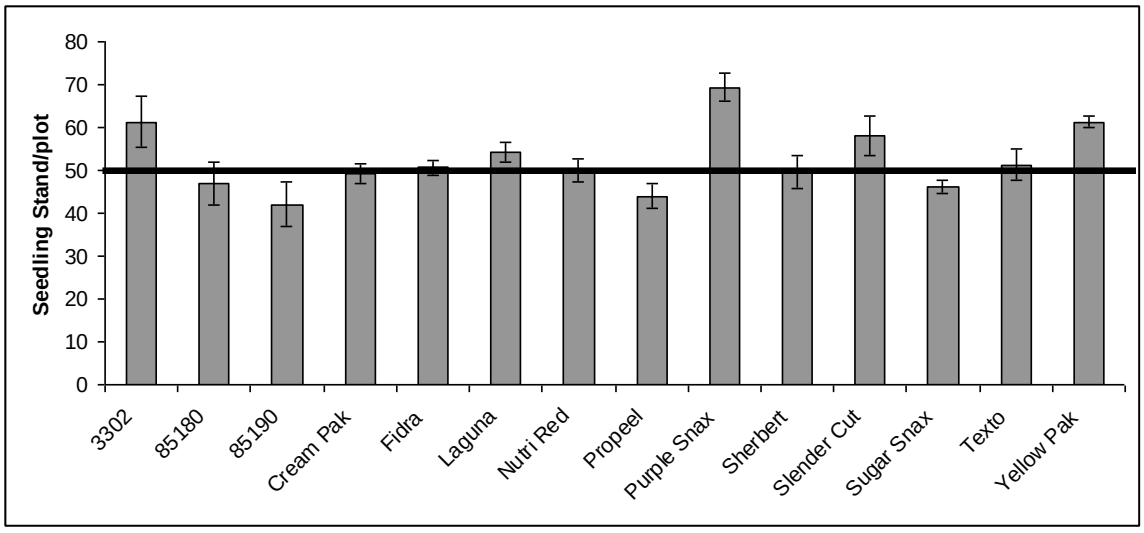

Figure 2. Early season stand measured 21 days after planting. Bars indicate the average number of seedlings/1-m long X 1 row wide transect/plot. The horizontal line represents the average stand in the adjacent beds (var. Enterprise).

Foliar Disease - For the conventional site the most prevalent foliar disease was powdery mildew. Foliar symptoms of powdery mildew were apparent from mid-August onwards and the grower followed a conventional spray program. The disease symptoms were patchy throughout the field. Because we did not replicate our plots, i.e. multiple plots of each variety across the field, it is difficult to know if the levels of disease observed in the study are due to location of disease in the field or susceptibility of the variety. To account for possible location effects we also recorded the amount of foliar disease in the grower's carrots that were immediately to the North or South of each plot (Appendix 1). Thus the comparison is between the amount of disease in the test variety compared to the grower's standard growing adjacent (Table 4). The varieties 3302 and NutriRed had more powdery mildew than adjacent grower carrots and are perhaps more susceptible to powdery mildew (Fig. 3). These varieties maybe more suitable for early season plantings and early summer harvests - powdery mildew tends to be a concern in August and September (Pscheidt and Ocamb 2013). In contrast, the variety Purple Snax had much less powdery mildew than the adjacent grower carrots (Fig. 3), which suggests a tolerance at least to this foliar disease. Levels of foliar blight were low and patchy overall, with less than 1% of foliage showing symptoms in the grower's carrots. The varieties NutriRed and Fidra had more foliar blight than surrounding grower carrots; 20 and 7%, respectively. All other varieties had no to low (1%) foliar blight incidence.

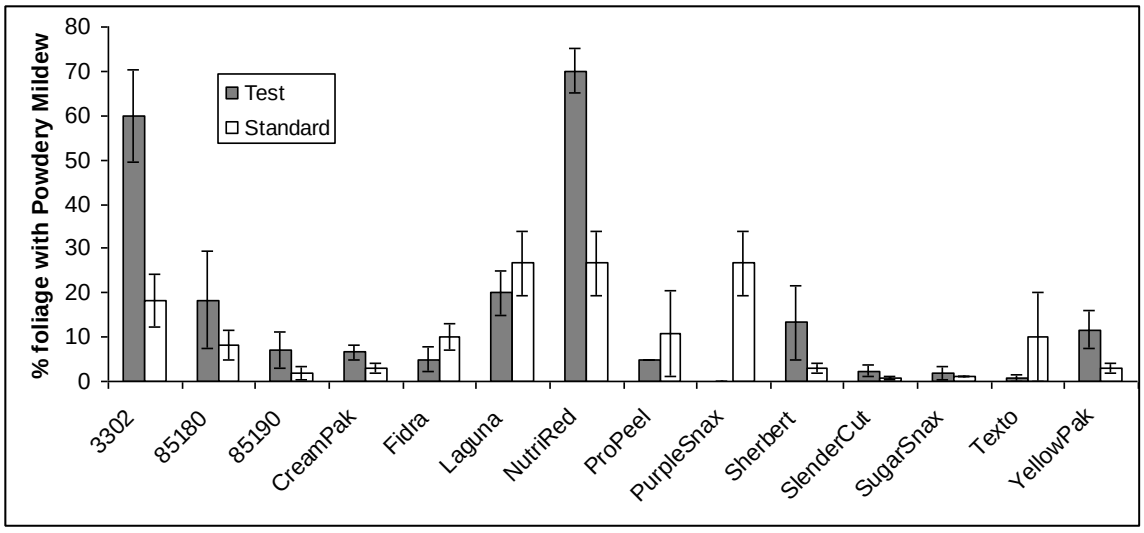

Figure 3. Comparison of powdery mildew severity on foliage in carrot variety trial plots (Test) and carrot plots in the grower's adjacent beds (var. Enterprise) (Standard). The bars represent the mean (± s.e.) percent cover of symptoms in three 1-m long X 1 row wide transects/plot.

At the organic site the amount of foliar disease on leaves and stems was minimal. This was surprising given that by mid-October foliar disease should be well established on foliage (Pscheidt and Ocamb 2013). However, the organic site was fairly isolated in terms of adjacent carrot production. In contrast, the conventional site was surrounded by carrot and parsnip production within a 10-km radius of the variety trial plots. Because disease pressure was so low we could not discern differences in susceptibility among the varieties at the organic site.

Insect Damage

Insect damage was only observed at the organic site and two types of damage were observed on roots. Firstly, we observed vertical or horizontal channels which were consistent with carrot rust fly feeding damage. Secondly, we observed holes in roots that were consistent with wireworm feeding damage. We recorded the relative number of roots harvested from the 1-m long X 1 row wide transect that had insect feeding damage and which type of feeding damage (Table 4). Varietal tolerance/resistance for rust fly has only been demonstrated on a few varieties, including Fly Away. In our trial, though, Fly Away did have some carrot rust fly feeding damage (Table 4). However, the overall size of our trial, the fact that it was a demonstration scale trial and the uneven growth of the crop due to weed pressure results in many confounding factors. For example, Theunissen and Schelling (2000) found that undersowing carrots with clover reduced carrot rust fly damage. The amount of damage observed for different varieties may be reflecting response of female flies to weed pressure within plots. Thus the presence of rust fly feeding on the Fly Away carrots should not be interpreted as a failure of the variety in reducing rust fly damage. Similarly, the lack of damage on NutriRed, Sherbert and Yellow Pak should not be interpreted as an indication of tolerance. Rather, we recommend that growers/industry continue to include rust fly damage as one of the evaluation criteria for future carrot variety trial work.

Further, variety trial work needs to follow a certain level of rigor in terms of trial design, in particular, evenness of growth across the trial area and enough replication or blocking to account for confounding factors (Williams and Roberts 2002). In addition to varietal tolerance, other tools (such as physical control using exclusion fences) have been shown to be effective for carrot rust fly control (Vernon and McGregor 1999). Exclusion fencing should not impact varietal performance, because fencing does not come into contact with the crop. However, the use of row covers and insect nets as barriers to carrot rust fly have also been proposed for organic carrot production. Varieties with more vigorous tops maybe more suitable for growing under nets and row covers. The compatibility of varieties with netting could be explored in future work. The wireworm damage observed in our plots should not be surprising since carrots are traditionally used as a method for baiting for wireworms (Arakaki *et al.* 2009). Wireworm damage in carrots has been reported in Ontario and other regions (Chaput 2000, R. Vernon personal communication, AAFC) however to our knowledge there are no widespread reports of wireworm damage in carrots in BC.

Table 4. Summary of insect feeding damage (percent of total roots harvested with feeding damage) observed at the organic trial site in Chilliwack BC. X indicates that carrot rust fly and/or wireworm damage were observed.

Variety	**% of carrots with insect feeding damage**	**Carrot rust fly**	**Wireworm**
Sherbert	0		
Laguna	7	X	
Yellow Pak	0		
Purple Snax	13	X	X
Cream Pak	9	X	
Napoli	2	X	
NutriRed	0		
Mokum	8	X	
Jeanette	6	X	X
Sugar Snax	14	X	X
Fly Away	6	X	
White Satin	*8*	*X*	

Yield

At the conventional site the varieties with higher yields than the industry standard carrots were 3302, Laguna, Purple Snax, Cream Pak, Texto and 85190 (Fig. 4, Table 5). Of these six varieties, the number of marketable roots was the highest for 85190, Purple Snax and Cream Pak. The majority of unmarketable roots for the other three varieties were due to forking. Forking in carrots can be due to a number of factors including biotic (root knot nematodes), and abiotic (soil compaction). No other symptoms of root knot nematode activity were observed, for example galling of fine root hairs, and the field had no prior history of root knot activity. Thus the forks were most likely due to abiotic factors. The varieties with yields lower than the average yield from the grower's beds were Fidra,

NutriRed, Propeel, Sherbert, Slender Cut and Yellow Pak (Fig. 4). For three of these varieties - Fidra, Propeel, and Slender Cut - the location of the plots (at the edge of the field) may have been a more important factor than variety on yield. Surrounding carrots from the grower's beds were also stunted in this area compared to the rest of the field. These findings underscore why replication of treatments across a trial area is so important for variety trial work (Williams and Roberts 2002). With multiple plots for all varieties we would have a better idea if some varieties are more likely to fork or not and on the true yield potential of a variety.

Table 5. Summary of yield parameters for carrot varieties harvested from the conventional site in Abbotsford, BC.

Variety	**Number of carrots/ transect**	**Weight (kg)**	**% marketable (excludes forks and splits)**	**Length of 10 marketable roots (cm)**
3302	44	4.01	86%	20.6
85180	29.5	1.66	91%	24.6
85190	27.5	3.98	93%	24.6
Cream Pak	39	4.23	88%	30.4
Fidra	41	1.88	89%	15.2
Laguna	44.5	3.01	88%	17.4
NutriRed	21.5	4.81	67%	20.5
Propeel	40.5	4.38	88%	25.6
Purple Snax	53	3.50	93%	27.6
Sherbert	40.5	1.61	91%	22.3
Slender Cut	39	1.28	88%	25.9
Sugar Snax	27.5	2.74	87%	28.2
Texto	48	3.40	94%	19.1
Yellow Pak	36	3.73	96%	27.3
Grower Standard (Enterprise)	39.5	3.57	87%	28.8

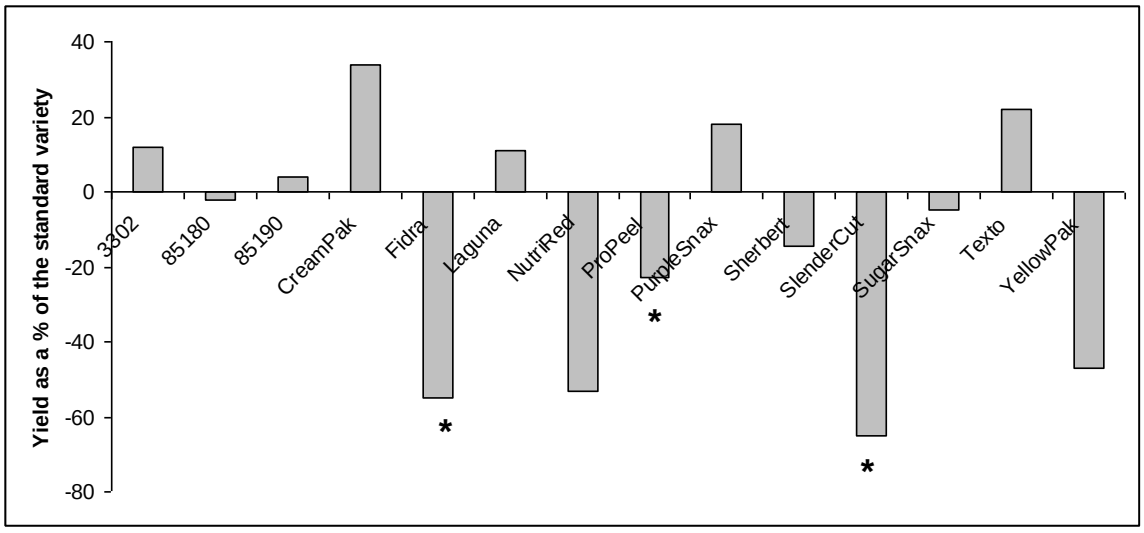

Figure 4. Yield of varieties at conventional site relative to the overall yield of the grower's carrots (var. Enterprise), sampled throughout the trial area. Bars with * below were located in the East edge of the field where overall growth (grower and variety trial carrots) was low.

Overall, the carrots from the organic site were much smaller than those from the conventional site (Table 6) and this again was most likely due to heavy weed competition and other differences in management - for example use of synthetic fertilizer versus no nutrient inputs. At the organic site, the highest yielding varieties based on weight were White Satin, Cream Pak, Purple Snax, and Jeanette. In terms of marketability White Satin, Purple Snax, Mokum and Fly Away had the fewest carrots with small roots, forked roots, or roots with splits. In terms of hand harvesting, we found that Sugar Snax was a very difficult variety to hand harvest, with lots of broken roots. In contrast the other varieties could be removed with less than 10% break.

Table 6. Summary of yield parameters for carrot varieties harvested from the organic site in Chilliwack, BC.

Variety	**Number of carrots/ transect**	**Weight (kg)**	**% marketable (excludes forks and splits)**	**Length of 10 marketable roots (cm)**
Sherbert	36	1.29	42%	13.6
Laguna	28	1.19	57	8.1
Yellow Pak	33	1.14	52	12.7
Purple Snax	30	1.54	67	15.9
Cream Pak	23	1.94	56	16.8
Napoli	45	1.35	42	11.3
NutriRed	27	1.50	50	13.9
Mokum	25	0.80	64	10.6
Jeanette	33	1.82	45	11.2
Sugar Snax	36	1.63	17	9.2
Fly Away	34	1.56	59	13.7

White Satin	24	2.20	75	16.3

Comparing the performance of varieties grown at both sites – Yellow Pak, Sherbert, Purple Snax, Cream Pak, NutriRed, and Laguna – we observe dramatic differences that highlight the challenge of organic carrot production (Table 7). Carrots are extremely vulnerable to weed competition, more so than other vegetable crops (Swanton *et al*. 2010, Dandy 2008) and this is most likely to be the biggest factor accounting for differences in our trial. Although the organic trial did not receive any additional nutrients, the soil was rich in organic matter and had been managed with cover crops and composts. For weed control in carrots flame weeding can be very effective either as a part of stale seed bed preparation or pre-carrot emergence (Rasmussen *et al*. 2011, Dandy 2008). It is unclear if there would be differences among carrot varieties in response to flame weeding, so we recommend that this be explored in the future. Also, while work has been done on establishing the critical weed-free period for carrots (Swanton *et al*. 2010), this work was done in Ontario and in the context of conventional production. We suggest that the critical weed free period(s) for organic carrot production needs to be determined.

Another difference observed between the organic and conventional site was the causes for unmarketable roots. For example, in the conventional site 30% of NutriRed carrots had splits, and in contrast very few NutriReds had splits at the organic site. Rather, at the organic site NutriRed carrots were unmarketable due to small size. This suggests that a variety like NutriRed may do better if harvested earlier and smaller (K. Sihota, personal communication, Canadian Farms Produce, Inc.).

Table 7. Comparison of the yield parameter for six varieties of carrots harvested from both the conventional (C) and organic (O) sites, in Abbotsford and Chilliwack, BC, respectively.

Variety	**Number of carrots/ transect**	**Weight (kg)**	**% marketable (excludes forks and splits)**	**Length of 10 marketable roots (cm)**
Sherbert (O)	36	1.29	42%	13.6
Sherbert (C)	40.5	1.61	91%	22.3
Laguna (O)	28	1.19	57	8.1
Laguna (C)	44.5	3.01	88%	17.4
Yellow Pak (O)	33	1.14	52	12.7
Yellow Pak (C)	36	3.73	96%	27.3
Purple Snax (O)	30	1.54	67	15.9
Purple Snax (C)	53	3.50	93%	27.6
Cream Pak (O)	23	1.94	56	16.8
Cream Pak (C)	39	4.23	88	30.4
NutriRed (O)	27	1.50	50	13.9
NutriRed (C)	21.5	4.81	67%	20.5
Sugar Snax (O)	36	1.63	17	9.2
Sugar Snax (C)	27.5	2.74	87%	28.2

Quality

Buyers assessing conventional carrots ranked carrots based on taste, overall appearance, length (suitable for clipped top bags) and suitability for processing over fresh market sales. While the majority of carrots were acceptable in terms of taste and appearance (Table 8) a few varieties were ruled out. For example, Texto was too short for the fresh market bags and Laguna roots were not consistent enough. Because this was a demonstration trial, qualities of carrots from the single plots may not be indicative of the true performance of each variety, as with other assessment parameters (e.g. disease). These buyers disliked the taste of 85190 and ProPeel, but ranked Cream Pak as the best tasting. In terms of appearance, Slendercut and ProPeel appeared to be suitable for processing into baby carrots however the buyer did indicate that most varieties are suitable if they are harvested at the correct time.

Table 8. Summary of quality evaluation by BC Fresh buyers for carrot varieties harvested from the conventional field in Abbotsford, BC.

Variety	**Taste**	**Length**	**Overall Appearance**	**Additional Comments**
3302	Good	Good	Good	Concern about Powdery Mildew levels in field
85180	Good	Good	Good	A good fresh market variety
85190	Bitter	Good	Good	
Cream Pak	Excellent	Good	Good	Best tasting
Fidra	Good	Good	Good	A good fresh market variety
Laguna	Good	Not consistent	Not consistent	Grower not interested in this variety due to appearance
NutriRed	Mixed – bitterness noted	Good	Good	Niche South Asian market; one buyer familiar with cooked flavour – better than raw
Propeel	Bland	Okay	Did not like	
Purple Snax	Good	Good	Good	Niche market
Sherbert	Okay – not special	Good	Good	Niche market; tough core not good for processing
Slender Cut	Good	Good	Good	Good for processing
Sugar Snax				Grower familiar with this variety and did not evaluate
Texto	Good	Too short	Did not like	
Yellow Pak	Good	Good	Good	Niche market

Evaluation of carrots harvested from the organic site by the organic buyer was done in a similar manner to the conventional evaluation. In addition to taste, the buyer also indicated which packaging options would be appropriate for each variety. Because the carrots were generally quite small, the buyer had some difficulty in fully evaluating some varieties (Table 9). Overall, the buyer indicated that there is a diverse market demand for organic carrots, for example in addition to fresh market they have markets for juicing carrots. The challenge for growers wishing to grow speciality carrots, for example

coloured varieties for baby bunches, is to develop relationships directly with chefs, local grocery stores or with bigger markets. By starting small, growers can develop production and marketing practices that will allow them to successfully expand production.

Table 9. Summary of quality evaluation by Discovery Organics buyer for carrot varieties harvested from the organic field in Chilliwack, BC.

Variety	**Taste**	**Appearance**	**Product Marketing**
Sherbert	Good crunch/flavour	Tops are okay	Rainbow bunches Bags (juicing/food service)
Laguna	Very sweet – buyers favourite	Hard to tell as carrots were still small	Probably good for bunching + Bags (table)
Yellow Pak	Initial bitterness, but okay	Some browning and leaf scars	Rainbow bunches – not stand alone
Purple Snax	Good flavour - unique	Good size – tops and roots Larger roots with swollen lenticles	Rainbow bunch; possibly purple bunch; bags (table)
Cream Pak	Crunch and good flavour	Good tops and very straight roots	Rainbow bunches Bags (table)
Napoli	Good crunch	Size good but tops look weak	* too small to adequately asses Probably okay for bunches if bigger
NutriRed	Good flavour	Bigger carrots look good with good tops	Rainbow bunch
Mokum	Flavour good but not special		* too small to adequately asses
Jeanette	Good flavour	Bigger carrots looked good – straight and good tops	Bunching and Bags (table)
Sugar Snax	Very good taste		* too small to adequately asses
Fly Away	Flavour is not very strong Crunch is okay	Tops seemed to flimsy for bunching	Bags (table)
White Satin	Unique taste, sweet	Tops dark green	Rainbow bunches; not a stand-alone carrot

Post-harvest storage parameters

Unlike other root crops, i.e. potatoes, beets, and rutabagas, carrots are susceptible to loss in flavour over the course of storage. However, some growers do successfully store carrots for several months (B. Wisbey, personal communication, Wisbey Farms). After four weeks of storage we observed a change in flavour for several varieties from the conventional site – 85180, 85190, Cream Pak, and Yellow Pak (Table 10). The change in taste for Cream Pak and Yellow Pak was especially pronounced as these varieties were among the favourites in the fresh tasting. We did not see any evidence of any fungal storage rots, but soft rot was observed on Laguna, NutriRed, and Yellow Pak. From the organic site, all carrots continued to be edible with only some bitter aftertastes (Table 11). For example, the difference in the post-storage taste of Yellow Pak from the conventional and organic site may be due to the fact that much smaller carrots were stored for the organic site, and that the harvest at the organic site had been delayed until light frosts had begun in Chilliwack. The difference in the post-storage taste between the organic and conventional site further highlights the need to ensure that variety trial work is replicated not just within a single field but also across sites and in terms of timing (Williams and Roberts 2002). The foliage of all varieties had some browning or yellowing of leaves that would require additional trimming before sale. The strongest stems and least amount of browning/yellowing were observed on Purple Snax, Cream Pak, Sugar Snax, Fly Away and White Satin (Table 11).

Table 10. Summary of post-storage taste test for carrot varieties harvested from the conventional site, Abbotsford, BC.

Variety	**Taste**	**Other**
3302	Good carrot taste	
85180	Good but bitter after taste	
85190	Mixed reviews bitter after taste	
Cream Pak	Mixed reviews - bitterness	
Fidra	Good sweet taste	
Laguna	Good carrot taste	Soft rot
NutriRed	Bitter but edible	Soft rot
Propeel	Good carrot taste	
Purple Snax	Good taste, different from regular carrot no bitter after taste	
Sherbert	Good taste, different from regular carrot no bitter after taste	
Slender Cut	Good carrot taste	
Sugar Snax	Good carrot taste	
Texto	Good sweet taste	
Yellow Pak	Inedible very bitter	Soft rot

Table 11. Summary of post-storage assessment for carrot varieties harvested from the organic site, Chilliwack, BC.

Variety	**% of foliage requiring trimming and stem quality**	**Taste**	**Other**
Sherbert	75% - strong stems	Different than fresh but still good	
Laguna	10% - weak stems	Good taste, no bitterness	Good crunch
Yellow Pak	25% - weak stems	Good taste but bitter after taste	
Purple Snax	30% - strong stems	Good taste, slightly different than fresh	
Cream Pak	15% - strong stems	Very good taste	Good crunch
Napoli	30% - weak stems	Good but bitter after taste	
NutriRed	50% - strong stems	Very bitter – even more bitter than fresh	
Mokum	75% - weak stems	Excellent taste, a sweet carrot	
Jeanette	30% - weak stems	Good but bitter after taste	
Sugar Snax	25% - strong stems	Good but bitter after taste	
Fly Away	35% - strong stems	Good taste, standard	
White Satin	25% - strong stems	Excellent taste, very mellow no bitterness	A consistent favourite

SUMMARY AND NEXT STEPS

The objective of this work was to conduct carrot variety trials in BC, with a focus on organic production and processing. We conducted this study as a demonstration with little or no replication of varieties within a site. This limits the conclusions that can be drawn from the results. However, since it has been close to 20 years since the last third-party carrot variety trial in BC, we feel we have begun a process that we hope continues. In other areas, specifically Brittany, France, researchers and growers have come together in the framework of a Participatory Plant Breeding program (Chable *et al*. 2008). Similar activities are starting across Canada and variety trial work can be incorporated into these programs. The minimum criteria for a rigorous variety trial includes a minimum of four replicates of each variety within a field, an industry standard variety as comparison, and using standard production practices. Following standard production practices ensures that growers will have similar results and also ensures success of trials. For example, in our 2012 trial making our own seed tape was an efficiency from our perspective as researchers, however it was not a standard production practices for even small scale growers.

In terms of variety performance, the combined results of this study suggest that several varieties are good options for organic growers to explore. The market potential of coloured varieties in particular should be explored further – with Purple Snax, Cream Pak and Yellow Pak ranking well with both buyers in terms of taste and performing well after

storage. Mokum and Fidra were two interesting orange carrots that performed well on a number of criteria, including taste. However, the poor performance of a variety in this trial does not indicate that it should not be considered for future plantings, for the reasons listed above. There is great potential for variety trial work to be incorporated with the other research needs of organic carrot production. For example, nutrient management, biofumigation with cover crops, tolerance to pests (Yarger and Baker, 1981) and some weed control techniques are all management practices that may impact varietal performance. Combining studies may be an efficient way to ensure that variety trial work continues (Williams and Roberts 2002) for BC organic vegetable production.

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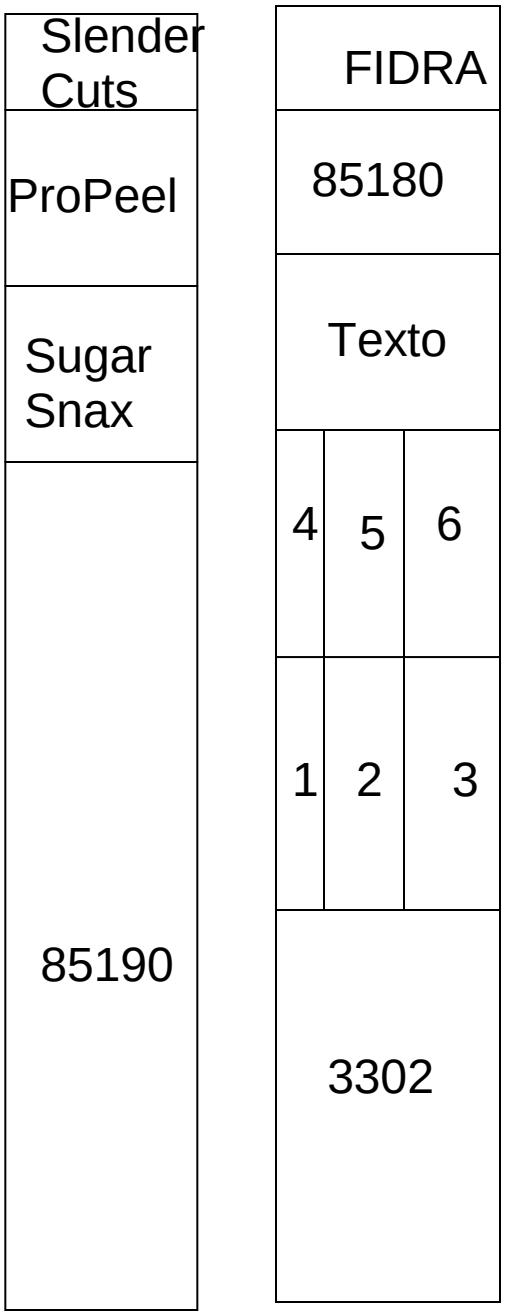
Appendix 1. Plot map for field trials

Vitana	Grivola
Tendersnax	2289
Vitana	Topcut
Enterprise	Magnum
Soprano	55205RZ
Olympus	Achieve
Uppercut	HMX2294
Crispy Cut	Crofton
Betero	Cellobunch
Crofton	Romance
Olympus	Tendersnax
55205RZ	Achieve
2289	Crispy Cut
Uppercut	Soprano
Cellobunch	Magnum
Grivola	Jerada
Betero	Romance
Vitana	Topcut
HMX2294	Enterprise
Crofton	55205RZ
Vitana	Enterprise
Crispy Cut	Tendersnax
Olympus	Achieve
Magnum	Romance
Cellobunch	HMX2294
Betero	Topcut
Grivola	2289
Uppercut	Soprano
Cellobunch	Jerada
55205RZ	Romance
Soprano	Jerada
2289	Crispy Cut
Crofton	Enterprise
Achieve	Topcut
Magnum	HMX2294
Vitana	Tendersnax
Grivola	Betero
Uppercut	Olympus

2012 Field Site

Jerada	Uppercuts
Romance	Topcut
Vitana	2289
55205RZ	HMX2294
Olympus	Betero
Magnum	Cellobunch
Crispy Cut	Grivola
Enterprise	Tendersnax
Crofton	Soprano
Achieve	Achieve
Magnum	Soprano
Cellobunch	Crofton
2289	Topcut
55-205RZ	Enterprise
Olympus	HMX2294
Grivola	Betero
Crispy Cuts	Romance
Vitana	Tendersnax
Jerada	Uppercuts



2013 - Conventional Site

4 = Yellow Pak
5 = Sherbert
6 = Cream Pak

1 = Laguna
2 = NutriRed
3 = Purple Snax

2013- Organic Site