Germinating Ideas: Carrot Seed Production in Isolation Structures
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About BCSeeds and FarmFolk CityFolk

FarmFolk CityFolk Society (FFCF) is a non-profit charity that works with farm & city to cultivate a local, sustainable food system. Since October 1993, FFCF has been engaging in public education; actively organizing around local, timely issues; building alliances with other organizations; and harnessing the energy of our volunteers. FFCF’s programs are provincial in scope. Starting Feb 2013, FarmFolk CityFolk entered into a four-year contract with USC Canada to coordinate the Bauta Family Initiative on Canadian Seed Security for the BC Region. For additional information on FarmFolk CityFolk check out our website: http://www.farmfolkcityfolk.ca.

FarmFolk CityFolk’s Seed Security Project is informed and directed by BC Seeds, a committee of dedicated BC organic seed growers. BC Seeds administers a seed listserv of over 300 subscribers, publishes educational resources, including a series of How-to videos called Seed Works, and hosts the bi-annual BC Seeds Gathering.

For more information, visit http://www.bcseeds.org.

About the Bauta Family Initiative on Canadian Seed Security

In 2011 USC Canada, in partnership with Seeds of Diversity Canada, received funding for a pilot year, beginning in 2013, to explore the state of seed security nationally. The initiative, named the Bauta Family Initiative on Canadian Seed Security, works to develop an understanding of the challenges and opportunities related to ecological seed production, distribution and conservation in Canada. The Bauta Initiative engages farmers, gardeners, researchers and organizations to support and strengthen existing seed work, and fill gaps where resources are most needed. BC has two regional coordinators that work with 4 other regions across the country to advance an ecological and diverse seed system in Canada.
Executive Summary

Thriving local food systems rely first on thriving local seed systems. The resurgence in interest towards ecologically grown seed marks an important moment in the movement towards relocalization of BC’s food systems. As global access to seed has become consolidated by a few multinational corporations, farmers, gardeners, activists and researchers have promoted a different direction, creating access to regionally adapted, genetically resilient seed held in the public domain.

Small-scale ecological farmers are taking up the task of relocalizing seed through innovation and collaboration. Many are focusing on how to make a livelihood producing seed for the fast-growing organic seed market. Arising from new research, conferences, roundtables and countless conversations in the field, BC Seeds, a project of FarmFolk CityFolk, set out in 2013 to explore how to increase quantity and quality of one major vegetable crop in BC.

For the growers in this year’s project, carrots (Daucus carota) were identified as a key crop in both their market and seed operations. That said, carrots are one of the more complex seed crops to produce. First, the crop is a biennial that requires two years to grow out and specific overwintering storage requirements. Secondly, domesticated carrot will readily cross with Queen Anne’s Lace (Daucus carota var. carota), a progressively common weed in British Columbia. Complete isolation between the wild and domesticated varieties is necessary to produce true-to-type seed.

The long-term objectives of this 4-year project are, broadly, to increase the viability of growing organic and ecologically grown carrot seed in high tunnel isolation structures. In addition to addressing the reality of cross-pollination with Queen Anne’s Lace, the outcomes generated by this research will also point to best practices in increasing the yield of regionally adapted seed through the potential of growing out multiple carrot varieties without cross-pollination.

Included in this report is an overview of carrot plant physiology as well as a concise outline of growing carrots for seed. Anecdotes from the growing season are woven throughout the report to offer further detail. Data was collected from the four participating farms and analyzed to provide documentation and insight as this project steps into its second year. Limitations and barriers are briefly discussed.

The report is concluded by a summary of on-farm learning, including future amendments to methodology, seed weight, tunnel design and pollinator introduction.
Small-scale organic and ecological growers benefit most from seed that is grown under the same diverse, and often unstable, circumstances as their market crops. This is where conventional seed production fails, occurring within controlled environments often with synthetic fertilizers and pesticides disallowing selection for traits such as disease resistance and quick germination. While industry consolidation has significantly eroded the scope of crop type and variety available to growers around the world (Navazio, 2013), the shift towards regionally adapted seed upholds organic and ecological growers as purveyors of the vast (if rare) number of locally and traditionally important varieties. It is an undeniably ambitious task, but one that remains pivotal if a wide breadth of diversity and locally adapted varieties are to be maintained.

Farmers are taking up this task through innovation and collaboration. Many are focusing together on how to make a livelihood producing seed for the fast-growing organic seed market. Farmers who grow ecologically sustainable food for market require seed that meets the needs of consumers as well as ecological cropping systems. More and more, consumers are espousing an ethic of local, sustainable and ethically grown food with qualities counter to what large-scale agriculture denies—food that is in season, nutritionally dense and tastes great. The seed purchased for the staple crops in Canada are predominantly grown under conventional cropping systems (Bauta Initiative, 2013). This disservice to our agricultural systems is profound, as resiliency is undercut by loss of on-farm biodiversity.

Foundational to organic and ecological farming systems are measures to promote biodiversity, and the on-farm realities of these systems are unlike those of conventional agriculture.

The seed available to organic and ecological farmers necessarily has to reflect these unique realities.

**The BC Regional Seed System: Building Momentum**

In 2007, BC Seeds surveyed over 150 BC farmers, many of whom reflected a difficulty in sourcing organic seed in desired varieties for their organic systems. They also stated a strong desire to incorporate more organically grown seed into their operations, if it were available (Wells, 2007).

A provincial gathering in 2012 brought together over 100 participants keen to build up seed sovereignty in the region. Next, 2013 brought about the launching of the Bauta Family Initiative on Canadian Seed Security. This initiative, national in its scope, implemented BC as one of five focus regions participating in an Applied Research Program. Leveraging the momentum from the conference and the nascent national seed security program, members of BC Seeds conceived of a research project that would bring together BC seed producers to make the next concrete steps towards increasing regional seed security.
Farmer-Initiated, Farmer-Led

In British Columbia, organic farmers lament the loss of funding in 2010 for organic extension agent services, which ran for 3 years before funding was eliminated (COABC, 2011). With no replacement for organic extension services, knowledge sharing amongst farmers provides a way to address challenges collectively and build the capacity of organic farmers (Roessler, 2013). One model of farmer knowledge sharing is through farmer-led research. This type of research design unsettles the dynamic of farmers as the recipients of research, instead positioning farmers to guide research goals and objectives, and determine what recommendations are relevant to their practices.

For this project, farmers are the driving force. The decision was made to grow out carrot plants for seed production under ecological farming conditions in four unique climates, over the span of four years. In this first year, each farmer built their tunnel environments, kept outside controls, and recorded their findings. Great strides were made to regularly check in with the project participants and review the methodology as needed.

Throughout the report, the four farming participants are referred to interchangeably as ‘farmers’ or ‘growers’. Occasionally both terms are utilized to imply a greater category of people in the world of organic agriculture. Care has been taken to provide clarity in this regard.

The intent of this detailed final report is to provide a record for future years of the project, as well as to mobilize knowledge for communities wishing to undertake similar farmer-led research. Building on the good work of farmers, breeders, researchers and advocacy groups before us, we present here best practices, research methodology, summaries of research findings and anecdotes from our season in the field.
The Farmers and the Farms

Patrick Steiner; Kootenay Joe Farm/ Stellar Seeds, Johnson’s Landing

Stellar Seeds is an independent, family-run seed company, based in the West Kootenays of British Columbia. Patrick Steiner and Colleen O’Brien grow many of the seeds on their property, Kootenay Joe Farm in Johnson’s Landing. Stellar Seeds also partners with other local, organic growers who supply the remainder of the seed catalogue. Stellar Seed’s focus is on providing the grower with high quality, open-pollinated, GMO-free seed. Many of the varieties offered are heirlooms, favoured by gardeners and farmers for many years because of tried-and-tested qualities like reliability, great flavour, and unique appearance.

By growing these seeds organically the plants become better adapted to thriving in the soil and cultural conditions of organic gardens and farms; on-farm selection results in seeds that are naturally more resilient to pests and pathogens, as well as capable of performing well in many growing conditions.

Stellar Seeds believes in a mixed farming approach, with on-farm diversity as a central tenet for guiding daily decisions. For this reason Kootenay Joe Farm not only grows seeds, but also other food crops for sale at local farmers markets. They have also incorporated animals on the farm, currently raising goats and chickens. These animals provide food, fertility and companionship and are an important part of the long-term sustainability of the farm.

Sharing knowledge and educational outreach is important to both Colleen and Patrick. They support both their own educational development and that of the larger community of farmers and growers they are connected to by holding workshops on seed production and offering learning opportunities to young, aspiring farmers interested in learning about organic seed-growing and market farming practices.

Kootenay Joe Farm is on the slopes of the Purcell Mountains in southeastern British Columbia. With full southern and western exposure, days are hot and full of sunshine in the summertime. Temperatures routinely reach above 30°C. Lows on summer nights are close to 10°C. Winters are mild with average temperatures at -5°C, and short cold spikes to -20°C. The soil is sandy and rocky, porous, low in organic matter and fertility. Addition of compost and other amendments is an important part of achieving good yields and maximizing plant health.

Patrick considers carrot seed as a cornerstone of the Stellar Seed’s business. He is proud to have provided a great quality, well selected line of open-pollinated Nantes Coreless carrot for the last 10 years, consistently well-received by customers. This past season was his first growing carrot seed in high tunnels. He went through a steep learning curve, identifying areas that require careful
management by the grower, specifically heat management within the tunnels, air flow and humidity monitoring, and regular timing of introduced pollinators. His first year yields were lower than his yields for field-grown carrots, but germination tests have shown great results for the high-tunnel seed. In succeeding years Patrick aims to fine-tune the practices for high-tunnel seed production and achieve great seed yields with good germination.

Sue currently runs a seasonal nursery in Sorrento, BC which was intended to be her retirement project. Now, with the nursery and her commitment to seed production, she is finding it hard to fit retirement in.

Project Coordinator Heather Pritchard (L) and grower Sue Moore (R)

Sue Moore; Sudoa Farm, Sorrento

Susan Moore has had a Certified Organic farm in BC since that option was available; first with Wild West, then BCARA and for the past 16 years with NOOA. Her seed growing started about 12 years ago after meeting Patrick Steiner and becoming fascinated by the completion of the farming process. Now seed production is a passion, a necessity for food/farm security as well as a source of income. The carrot seed project has caused her to reflect on all her seed growing techniques, not just those of carrots, and to renew her commitment to selecting and growing quality and reliable seed for farmers and gardeners.

Mojave Kaplan; Planting Seeds Project, Lytton

Planting Seeds Project (PSP) has been intensively farming & growing seeds on approximately 3 acres of arid steppe (semi-desert) flat plateau lease land of the historic Earls Court Estate, a short distance from the shoreline of the mighty muddy Fraser River, since 2000. The field is situated on the west side, out of Lytton, the “hotspot of BC”, and is graced with abundant clean water and clean air. Substantial isolation from all local agriculture by forest, hillside and river, makes it ideal for seed production. The sole neighbor at the north end of the...
field (upwind) also grows for seed, and coordinating crops for seed purity has been ongoing.

Productivity for this soil, damaged by chemical farming of squash 20 years prior to turning the soil, has demanded knowledge of soil biology and permaculture to transform the quickly draining alkaline sandy site, (producing wild grasses of only 2-3") to the present sandy loam. At that time, no friendly weeds would grow (imagine no chickweed, plantain, lambs quarters, or amaranth!), only knapweed, black nightshade, and purslane with almost no leaf, just stems to strangle anything daring to grow. Intense heat, sunshine, and relentless winds are the growing conditions. Most seed grown in this semi-marginal field will find it much easier to grow in a well-prepared garden, making this an ideal field for high stress selection for seed production.

Mojave Kaplan's first substantial seed crop was Siberian Kale (the last known package from this grow-out vivaciously germinated 19 years later!) She moved to Vancouver in early 1990s to co-create Planting Seeds Project, where she worked as part of the collective store Circling Dawn Organic Foods, which would become the first Certified Organic Store in North America. PSP also worked on local seed banks, initiatives to head off GMOs, and traveled abroad to share seed. In 1992, the first carrot seed crop was harvested. Through Planting Seeds Project, she brought the first pound of Purple Dragon carrot seed into BC, also in the early 1990s, later tracing the seed back to John Navazio's original release through Garden City Seed.

The carrots for this project were grown at Fountain Mountain Farm in the Fountain Valley near Lillooet, BC, where Planting Seeds Project was contracted to open fallow grazing land, resulting in very successful first year gardens. Carrots were carefully selected and planted in the wooden tunnel house in Lytton for second year seed production.

Planting Seeds Project is looking forward to a very productive seed-growing year in 2014, and invites intern applications.

Jen Cody; Growing Opportunities Farm Community Cooperative, Nanaimo

Growing Opportunities Farm Community Cooperative became registered as a non-profit cooperative in 2013. Prior to that, Growing Opportunities had been running as a community farm for 6 years. In 2012 and 2013, Growing Opportunities has partnered with Farmship Growers Cooperative. Growing Opportunities runs educational programs for
people interested in farming, works with people who have challenges and disabilities, and does on-farm research. Farmship Growers Cooperative provides land and full time farmer mentors while they manage a for-profit vegetable production farming operation. The land is a total of 10 acres, 9 of which are deer fenced, with an adjacent 1 acre of unfenced land. The 1 acre parcel houses 3 high tunnels and a greenhouse in the lower portion, and an upper garden with two high tunnels and greenhouse. The property is located in Yellow Point, south of Nanaimo on Vancouver Island, and is a part of the Cowichan Regional District.

The area has a plant hardiness zone of 8. The moderate coastal climate is characterized by slight seasonal variations in temperature, with an average daily temperature in July of 17.9°C and 2.7°C in January. The site receives over 1900 hours of sunlight per year. While being moderate in climate, it is expected that lows in the winter will reach below freezing, and have been known to go to -15°C. Each year, the area experiences 1077 mm rain and 80mm of snow. The highest amount of rainfall occurs in October, November and December, while summer months are thought of as ‘dry’. Anecdotally, the farm is in a hot/cold pocket, typically experiencing 3 degrees hotter in summer and 3 degrees cooler in winter than forecast for Nanaimo.

There are two major soil types on the farm, peat and sandy/clay. While the peat soil grows incredible root veggies, they flood annually, usually from late September to mid May. As such, the peat soil areas are considered the farm’s greatest asset as well as the greatest challenge. Future plans will include increasing knowledge and expertise in managing peat soils.

Jen Cody has been growing carrot for seed for the past 5 years. The 2009/10 season was the first that she used a remay tent as a method to isolate carrots grown for seed from Queen Anne’s Lace. She continued to use remay isolation techniques in 2011/12. Initially, hand pollination was used rather than introduction of insect pollinators. Growing Opportunities and Farmship are well known for their market carrot production, particularly their rainbow carrots, which have been credited as a large part of the farm success.

Jen credits Mojave Kaplan for sparking her fascination with carrots and carrot seed. It was 11 years ago that Mojave sold Jen her first package of carrot seed, from the Planting Seeds Project. This seed was the Amsterdam Gold variety grown as one of the varieties for this project. Jen has grown that variety nearly every year since then for both vegetable production and, later, seed production. Jen has a great fondness for the wonderful qualities of this variety of carrot and continues to learn more about different varieties of carrot every year.
**Background**

Carrots are in the plant family Apiaceae (formerly Umbelliferae). All Apiaceae are dry-seeded crops, best suited to areas where rainfall during flowering or seed maturation is minimal or absent. Typically both the annual and biennial crops grown for vegetable markets and seed production, respectively, mature and are harvested in late summer into autumn.

The carrot flower is a compound umbel, with perfect flowers. Even though carrot flowers are hermaphroditic they discourage inbreeding by the stamens ripening earlier than the pistils, making self-pollination less likely to occur (though it infrequently does). The flowers are a source of both nectar and pollen. The primary, or king, umbel forms first [See text box 2], followed by the secondary and tertiary umbels a few days to weeks later.

All aspects of the plant contain volatile oils that lend to the plant’s characteristic aroma. Similarly, the level of terpenoids, a class of volatile organic compounds, imparts the fragrant ‘carrotly’ flavour of the roots. Terpenoid flavour balanced with sweetness factor determines a great-tasting carrot (NOVIC, 2012).

The biennial root will produce a seed head in the second year of growth. In order to flower, biennial plants need to undergo a process of vernalization, which induces floral growth through exposure to low temperatures, typically held between 1 and 3°C.
Queen Anne’s Lace (Daucus carota), native to Eurasia, is a biennial plant in the Apiaceae family that is increasingly prevalent in North America. In BC, it is common in the south west of the province and can be found in south central and east regions. It is sometimes referred to as wild carrot. Queen Anne’s Lace is occasionally cultivated for its use in herbal medicine.

Queen Anne’s Lace (QAL) has a strong taproot with a woody centre and bitter taste. Despite its flavour and being visually quite distinguishable, the root smells very similar to a carrot. Though it can be consumed when young, it is the dominant qualities found in the QAL taproot that cause concern for carrot seed growers in areas where the wild cultivar is present. Indeed, when we visited the Dungeness Valley in Washington (see text box 3), Jen snapped a telling photo of a ‘Wanted’ poster calling on local residents to support farmers in eradicating pernicious local QAL populations that might cross with carrot seed crops. The white colour is a dominant gene and expressed if a cross has occurred. A grower can also determine a cross by gnarled, hairy roots and/or a bitter taste.

Not surprisingly, the physiology of QAL is quite like that of domesticated carrot. The plant often reaches up to a metre in height. The flowers have a white inflorescence of numerous compact umbels, frequently with a scarlet flower in the centre. The delicate flowers resemble lace, giving the plant its common name. In BC, QAL will typically flower in July to September, potentially overlapping with carrot seed crops flowering dates. Leaves are fern-like, arranged bipinnately along the stem. The primary umbel forms first, followed by secondary and tertiary off the stem. Each flower produces two seeds, mature when brown and beginning to lift from the umbel surface. QAL seed, like cultivated carrot seed, has hooks that serve to hold the seed on to the umbel, but also cling to passersby who brush past the plant as a natural dispersal mechanism.

Growers from two regions, Sorrento and Lytton, reported no naturally occurring populations of Queen Anne’s Lace. Near Lytton, a substantial single patch of QAL came to the growers attention, which was allowed to flower and seed this year. It escaped a purposeful planting in a herb garden, approximately 5 km north of the growers field.

Nanaimo and Johnson’s Landing both have healthy populations of Queen Anne’s Lace. For growers in those regions, isolation is pivotal for carrot seed cultivation. Unlike the Washington growers, it is unlikely these BC farmers could maintain local populations to the necessary isolation distances. Until BC seed growers build the capacity to provide market growers with the bulk amounts of viable locally grown seed required for their operations, market growers will undoubtedly need to continue to purchase from larger seed companies to meet their needs.

**Text box 1: Queen Anne’s Lace and the problem of cross-pollination**

![Queen Anne’s Lace and the problem of cross-pollination](image)

Carrot (L) and Queen Anne’s Lace (R) Flowers. The plants at all stages are highly variable in appearance and extremely difficult to differentiate.
How-to of Carrot Seed-Saving

A defining activity of this first year of the project was our trip to the Dungeness Valley in Washington with project consultant John Navazio and his colleagues at the Organic Seed Alliance [see text box 3]. Here, a large portion of our day was spent workshop-style with John, brushing up on best practices for carrot seed production, including steckling preparation and storage, modes of reproduction and pollination, ideal climatic requirements and selection of traits from steckling harvest to seed harvest. This mid-season trip brought together the multiple actors of the research project for enriching conversation and allowed for focused discussion of each farmer’s particular issues with their carrot seed crop.

Below is a review of best practices in small-scale organic carrot seed production, informed by publications from the Organic Seed Alliance and our workshop in Washington. The majority of the information has been summarized from the recent publication, *The Organic Seed Grower* (Navazio, 2012) as well as publications from the Organic Seed Alliance in Washington (2010a; 2010b).

Mode of Reproduction

Carrots are primarily outbreeding plants. Some crops are strongly outbreeding (such as corn), but carrots will occasionally self-pollinate. However, this is rare, as the anthers (male part of plant) and stigma (female part of plant) typically mature at different points. Genetically, the offspring of outbreeders will be dif-

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**Table 1.1 Crop specifications for domesticated carrot Daucus carota.**
Adapted from *The Organic Seed Grower* 2013, Chelsea Green Publishing.

<table>
<thead>
<tr>
<th>Plant Family</th>
<th>Apiaceae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary mode of reproduction</td>
<td>Primarily cross-pollinated, can self-pollinate</td>
</tr>
<tr>
<td>Primary mode of pollination</td>
<td>Insect</td>
</tr>
<tr>
<td>Lifecycle to seed</td>
<td>Biennial</td>
</tr>
<tr>
<td>Seed production method</td>
<td>Root-to-seed or seed-to-seed</td>
</tr>
<tr>
<td>Isolation for commercial production</td>
<td>0.8-3.2 km</td>
</tr>
<tr>
<td>Temp. required for vernalization (°C)</td>
<td>1° to 3°</td>
</tr>
<tr>
<td>Relative humidity required for storage</td>
<td>90 - 95%</td>
</tr>
<tr>
<td>Ideal temp. (°C) for foliar growth</td>
<td>20° to 25°</td>
</tr>
<tr>
<td>Ideal temp. (°C) for pollination</td>
<td>27° to low 30°</td>
</tr>
<tr>
<td>Ideal temp. (°C) for seed maturation</td>
<td>30° to 35°</td>
</tr>
<tr>
<td>Potential cross-pollination</td>
<td>Queen Anne’s Lace (<em>Daucus carota var. carota</em>)</td>
</tr>
<tr>
<td>Planting spacing of stecklings</td>
<td>Seed-to-seed method: 4&quot; to 8&quot;</td>
</tr>
<tr>
<td>Crop type/ideal climate</td>
<td>Root-to-seed method: 8&quot; to 12&quot;</td>
</tr>
<tr>
<td>Minimum population number for genetic maintenance</td>
<td>Dry seeded/warm - hot season</td>
</tr>
<tr>
<td>Minimum of 150 roots, preferably 200</td>
<td></td>
</tr>
</tbody>
</table>

15
ferent from both parents plants, allowing adaptations in the offspring. Because of this mode of reproduction, maintaining sufficient population genetics is vitally important in commercial carrot production – too low of numbers result in undesirable inbreeding depression.

**Mode of Pollination**

A small degree of self-pollination can occur with carrots, but in general they are cross-pollinated. Insects are the primary pollinators of carrot plants, including flies and honeybees. Without adequate pollinator activity, carrot umbels will not set mature seed.

**Maintaining Genetic Variability and Population Size**

Carrots need large populations to avoid inbreeding depression. For commercial growers, a minimum of 150 plants is recommended. Adequate population numbers ensure multiple combinations of genetic material between plants, increasing the adaptability of the seed crop.

**Climactic Requirements**

Carrots are a dry seeded, warm to hot season crop, with ideal temperatures reaching 30°C with regularity, but not exceeding 35°C during and immediately after flowering. Later season temperatures exceeding 35°C can be tolerable. Rainfall while seed is reaching maturity can increase incidence of disease, and potentially reduce yields (OSA, 2010b).

Other factors to consider in determining crop success include length of daylight hours, amount of rainfall, timing of rainfall, soil type, insect pressure and local weed populations (OSA, 2010a).

**Isolation Distances**

The ideal isolation distance for domesticate carrot is often recorded as 0.8-3.2 km for commercial production. Barriers on the landscape may allow for a grower to err on the lower side of this recommendation. When growing out carrot crops, isolation distances need to be maintained between carrot varieties as well as wild carrot (Queen Anne’s Lace).

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**Text box 2: The King Umbel-selecting for the best seed**

Winds in the early days of tunnel construction found one grower with bent over carrot plants and a collapsed tunnel. The tunnel was successfully reinforced, but many of the central umbels of the carrot seed crop were lost. Seed was still saved from the plant but the specific loss of the central flower was notable.

The central inflorescence arising of the main stem in the second year of growth – often called the King or primary umbel – typically sets the highest quality seed (based on germination and seed weight) on the carrot plant (OSA, 2010b). As the first flower head, it sets the first seed. Secondary and tertiary umbels form sequentially following the primary umbel off branches from the main stem. The seed from these umbels is also saved for seed, but as their seed matures later and can be less robust than that of the King umbel, germination rates can be lower. Less commonly, seed from quaternary umbels can be harvested for seed.

Since the orders of umbels mature at different times, saving carrot seed is a balance of waiting for maximum maturity while avoiding seed loss. As a general recommendation, a balance is struck by harvesting when about 80% of the seed has reached maturity (OSA, 2010b). When a carrot seed is mature, it will lift off of the surface of the umbel, remaining on the plant only by the small hooks on each seed. As such, wind in the seed maturation phase is an issue for carrot seed growers.

This concept of selecting the most robust seed from a plant, while not always possible or economically viable, is a good practice for organic seed producers.
Preparing & Storing Stecklings

Carrot seed production utilizes one of two methods, either the seed-to-seed (STS) method or the root-to-seed (RTS) method. In the seed-to-seed method, the carrot crop remains in the field over-winter, exposed to low temperatures for the necessary length of time for flowers to form. The seed-to-seed method is most utilized by larger scale growers, and requires that the field environment is neither too extremely cold that the crop will be damaged or too mild that flowering will not occur. In the root-to-seed method, roots are harvested at optimal size in the first year of vegetative growth, stored under specific conditions, and replanted the following spring for the plant’s reproductive development. Despite the multiple steps required, the root-to-seed method has multiple benefits to carrot seed producers, allowing for selection, avoidance of potential extremes of outdoor environments, and some increased protection against diseases, insects and animals.

As a biennial crop, carrots must undergo a period of thermal induction known as vernalization to initiate flowering in the second year. For carrots, this period is generally 8 weeks held at 1 to 3°C, though there can be considerable variation between varieties in the length of time needed. Inadequate vernalization will result in the crop not flowering (and therefore setting no seed), thus this is a vital step to perform correctly. While low temperatures need to be held for proper vernalization to occur, freezing will damage the stecklings. Other factors that are key to overwintering success include carrot harvest at an appropriate size (if storing out of the ground) and protection from disease or pests.

When selecting carrot roots for seed production, characteristics to consider include colour, flavour, disease resistance, shape, resistance to bolting and sturdiness of leaves for bunching. The Organic Seed Alliance suggests that if the stecklings are to be stored out of the field for many months, it may be ideal to grow the crop to market maturity so that the grower can evaluate certain traits not present when smaller (such as root shape). Otherwise, the crop can be harvested and stored at around 2 cm, though a carrot can begin vernalizing at 4-8 mm.

Spring dig: The carrots collected on the ground, are the first selection of roots to be replanted for seed production. The first selection was made by selecting carrots meeting the criteria of blunt ends, smooth skin, no knobs, straight, alive crowns, and a general feel of health and vigor.

The carrots in the bucket are for food/ juicing purposes.
In addition to average 8 weeks required for vernalization, proper steckling storage is imperative for the grower in climates where the ground cannot be worked for many months. The following are steps to optimally prepare roots for storage if utilizing the root-to-seed method of production.

Some hands-on practice with the methods below is recommended before carrying out on important seed crops.

1. Harvest roots on a clear day during dry conditions. If this is not possible, it is important to allow wet roots to mostly dry before storage.

2. Clean roots of majority of soil, using your hand or gently shaking, taking good care not to damage the root that now needs to store for multiple months. It is not recommended to use water to clean the roots, as this will likely contribute to decay. A very small amount of soil remaining on the root is acceptable.

3. It is vitally important to prepare the stecklings for storage in the long-term by trimming the leaf tops and petiole (or leafstock) to prevent rotting of the growing (or apical) bud. This step is a balance between removing enough of the petiole to avoid rot while avoiding cutting into the bud. The Organic Seed Alliance recommends starting out with a sharp knife and beginning to trim the petiole from the crown with upward cuts until the amount remains is about 1.3 cm from the base of the crown of the carrot, and tiny fern-like leaves are present. Too much has been cut if the outline of the round stem is visible.

4. A fourth step of cutting the root end is optional but practiced by many growers. This step is carried out in the spring before transplanting. Cutting the roots serves multiple functions.

First, cutting into the carrot reveals characteristics such as core size, colour and flavour. Secondly, it creates ease in transplanting, as the cut is made on a diagonal and a shorter hole is needed. If choosing this step, the cut roots must be left to heal over, or ‘suberize’, for several hours. The roots, typically cut to 3-4 inches, are then transplanted more efficiently than if left full length, particularly for larger varieties.

As stated above, vernalization of carrot seed crops can occur in the field or in a controlled environment such as a cooler or root cellar. Out of the field, a cooler with access to temperature control is ideal, as a few degrees in either direction can mean the loss of a crop. A root cellar is more difficult to maintain at the optimal temperature, particularly before the winter months come on. Carrot roots are the vegetative part of the plant where carbohydrates are stored. Above 3°C, the stecklings will respire more intensively, which will in turn expend their carbohydrate reserves.

As with most biennial stecklings, carrots prefer a relative humidity of 90-95%. Relative humidity can be controlled in a variety of ways. The most reliable is with the use of a humidifier, which allows the roots to be stored in open wooden or plastic totes as long as there are small openings to allow for even flow. John Navazio recommends a 2-3" layer of wood shavings on top of the roots (not sawdust), preferably cedar due to antifungal constituents.

In a root cellar, relative humidity can be achieved through layering the carrot roots between clean, slightly damp materials such as sand or leaves.

A final way to achieve relative humidity, utilized by our growers, is to store the roots in plastic bags prepared so moisture can escape. Prepare the bags with at least 3-4 rows of small circular penny-sized holes across
the middle of the bag with the addition of a few handfuls of wood shavings. The plastic bags create the necessary humidity while the shavings manage any condensation.

It is recommended to check the stecklings every 6-8 weeks and remove any rotten roots.

Proper steckling preparation and storage is crucial for overwintering survival, and many resources provide further detail for the new grower. See the Organic Seed Alliance’s guide *The Principles and Practices of Organic Carrot Seed Production in the Pacific Northwest* (2010) or *The Organic Seed Grower* (2013).

**Spacing**

It is recommended to amend spacing for seeding depending on the seed method utilized (OSA, 2010). For the seed-to-seed method, seeds are sown less heavily than if growing using the root-to-seed method.

Steckling spacing recommendations range depending on the variety grown. Small stature varieties such as Nantes varieties are planted 4” for STS and 8” for RTS. Wider carrots varieties have a recommended spacing of 8” to 12” for either RTS or STS.

**Open-Pollinated**

All varieties grown out for this project are open-pollinated (OP), referring to seed that is produced through natural pollination mechanisms. Unlike hybrid seed, the genetics of OP crops are generally stable and so if seed is saved from a plant one season, it can be grown out the next with offspring that is true-to-type. In this way, open-pollinated varieties can be saved by any grower with a certain amount of knowledge of that crop and seed saving in general. Hybrids, conversely, cannot be saved in the same way, as their progeny won’t come ‘true.’

Open-pollinated varieties have been neglected in modern plant breeding, and this has important consequences for varietal upkeep. A quick search of the top national organic seed purveyors reveals fewer choices for open-pollinated carrot seed. Luckily, open-pollinated varieties have been maintained and shared by seed enthusiasts, including farmers in this project, and their production is being met with renewed interest.

**Seed Harvest**

Carrot seed is harvested when it is dry, papery brown in colour, and has begun to lift off of the umbel. Harvesting requires that the grower find the balance between waiting long enough for mostly full maturation and losing seed due to weather conditions [see text box 2]. A notable benefit of utilizing high tunnels in carrot seed production is the season extension afforded to the grower.
The Carrot Project crew was hosted mid-season in Washington by the good folks working with the Organic Seed Alliance, including plant breeder and project consultant John Navazio, OSA staff member Laurie McKenzie and OSA Executive Director Micaela Colley and family. We toured around the Dungeness Valley region, home to Nash’s Organics Produce. Here, ongoing successful seed breeding programs, including carrot seed, exemplify an effective partnership between farmers, universities and seed advocacy groups.

There was a palpable excitement as we drove up to one of Nash Huber’s fields. Nash’s name is well known in the Pacific Northwest seed world. As an economic driver of the county, Nash has played a tripartite role – promoting increased access to quality organic seed, keeping land in agricultural production, and training up a new generations of farmers. Today, Nash’s Organic Produce is grown on roughly 450 acres, and his operation is known for superior carrots (replacing what John refers to as the pervasive carrot-shaped “tent pegs” found in grocery stores). In addition to market carrots, Nash’s farms participate in participatory plant breeding projects and produce about half of their own carrot seed despite the growing, yet still manageable, presence of Queen Anne’s Lace in the region.

John took us around Nash’s operation to see distinct stages in the carrot seed lifecycle. We visited fields in the process of being flame-torched to combat weed growth pre-seeding and a carrot seed isolation structure. Of course, we did not miss the chance to stop by Nash’s farm store and sample the subject of our inquiry.

Our hosts spent the day weaving Nash’s story with the broader resurgence of organic seed saving and participatory plant breeding. Part classroom time and part in the field, our team was able to share knowledge, anecdotes and skill with one another, while tapping into John’s years of breeding experience. It was invaluable to spend time face-to-face both for addressing the efficacy of the research process and deepening relationships.

In the classroom, we were schooled in ideal storage preparation and conditions, selection and population management, new knowledge around vernalization and stages specific to carrot seed production. Not to mention, we said the word ‘steckling’ a record number of times.

Visiting John’s caged carrot flow- ers, we spent a good deal of time working through the specifics encountered by each BC farmer in their unique microclimates. This farmer-to-farmer conversation was invaluable for us, as was the experience of seeing another established carrot seed operation. Over the course of one very full day, cross-border relationships were built and strengthened. Naturally, this occurred over beautiful food as we finished the evening off with a dinner of local organic fare.
Research Goal and Objectives

Project participants designed research methodology to address the goal of increasing ecological carrot seed production regionally. Successful production of the quality and quantity of carrot seed in BC needed for regional seed security will largely be determined by successful utilization of high tunnel structures.

The objectives of this on-going research project are twofold:

1) Determine and make recommendations for the ideal infrastructure needed to grow carrot seed in a tunnel environment, including key factors such as climate control, pollination, soil fertility, irrigation regime and timing of planting and harvest.

2) Provide cross-regional analysis and sharing of data with the seed growing community

In this initial year, a tertiary research objective was to evaluate and refine the research methodology for subsequent years. The swift progression from project conception to implementation required some trade-offs for project design and methodology, discussed in Limitations and Barriers, and addressed further in the Summary of Findings.
Research Design & Methodology

Project Participants

Farmers

The efficacy of cultivating carrots in tunnels, for the purposes of seed production, was explored using a farmer-led research model during the months of April to October 2013 in four different regions of BC. Participating farmers in Johnson’s Landing (Kootenay region), Sorrento (Shuswap region), Nanaimo (Central Vancouver Island) and Lytton (Fraser Canyon region) grew one to two varieties of carrots in both tunnels and in-field. In-field carrot crops were intended to act as controls in those areas where Queen Anne’s Lace (QAL) was present, as the seed set by these plants would have undoubtedly crossed with the wild carrot plant. In Sorrento and Lytton, where QAL is not present, these outdoor beds of carrots demonstrated how a farmer in similar conditions might grow multiple carrot varieties without adhering to the recommended isolation distance of 0.8-3.2 km.

The participating farmers seed growing experience ranged from 5 years to over 20 years. All grow using certified organic or ecological growing methods and are considered small-scale.

Project Coordinators and Support Staff

The coordinators for this project are also members of the BC Seed growing community, as well as the BC regional coordinators for the Bauta Family Initiative on Canadian Seed Security. During the growing season, project coordinators and communications staff from Farm-Folk CityFolk visited three of the four farms to document and get a firsthand look at the individual tunnel designs and crop progress.

Project Consultants

Martin Entz and his colleagues at the Natural Systems Agriculture lab at the University of Manitoba offered their knowledge of organic cropping systems, as well as brought expertise in collaborative study design. Anne Kirk from Natural Systems Agriculture attended the Washington field day in July to further consult on the project.

John Navazio co-founded the Organic Seed Alliance in 2003 and is one of the best-known and respected organic plant breeders in North America. John’s encyclopedic knowledge of organic systems, plant breeding and seed production provided mentorship for the duration of the growing season, including a one-day field visit to Washington.

Working with researchers from University of Manitoba and Organic Seed Alliance aided in the process of developing research protocol, and frequent teleconferences allowed for methodology revision as needed along the way.

Carrot Varieties

Six different varieties of carrot were grown throughout the different regional experiments; five in tunnels (Nantes Coreless, Amsterdam Gold, Purple Haze, Burlicummer, Nantes Forto) and one in field in the two regions where QAL was not present (Purple Dragon in both cases) [Table 2.1]. In the two regions where QAL was prevalent, the two farms maintained a control of the in-tunnel variety outside to observe plant vigor and pollination success. In one case, the contaminated seeds from this outside control underwent germination testing to compare with those seeds grown in
Farmers planted anywhere from roughly 100-400 stecklings per variety. Seeds were originally sourced from around British Columbia and, given the lifecycle of biennial crops, all stecklings were grown out on one of the participating farms the season prior and overwintered either in cold storage or, in the case of two varieties, in the ground. In one case, a grower was able to source stecklings from another grower in the project.

**Tunnel Design**

All farmer participants utilized differing tunnel designs for their seed crop. Two growers made use of preexisting structures, augmenting with screen to allow for better temperature regulation. The remaining two growers constructed tunnels once their crop was established.

Varying dimensions of designs are included in Table 2.1.

Of the preexisting designs, both used 60g 1.9 mm x .095 mm. netting. One design used 60% netting and 40% greenhouse poly plastic.

The other preexisting greenhouse was adapted for carrot seed production by installing netting for the entire length of the end walls using heavy duty staples, with greenhouse poly for the length of the side walls. A 2’ wide roof vent was installed, inspired by a split in the already existing plastic.
One of the tunnel designs erected this season made use of recycled metal circles, cut into ‘U’ shapes. Three foot lengths of pipe were pounded into the ground with a hole drilled into each pipe. A screw was inserted into each hole along with a piece of wood to act as a stopper for the metal ‘U’ pieces. The ‘U’ arches were inserted and then covered with greenhouse poly, secured with rocks. The ends of each tunnel were covered with mesh netting. Two ventilation windows were installed mid-season to help mitigate the high summer temperatures.

Completed row of hoops ready for plastic and netting. Note that the carrot crop was well established before it was covered.

To attach the netting, split PVC tubing clips over the netting and metal hoops.

A wooden stopper inside the tubing secured by a screw keeps the metal hoops in place.
A ridge pole was added for stability.

To mitigate the high temperatures inside the tunnel, several vents were cut into the poly walls. The vents were then covered with netting and taped into place.

Jen Cody’s twin tunnels with a control group of carrots at the end. A control group makes it possible to assess how growing in tunnels affects the overall growth and health of the carrot crop.
Finally, a fourth tunnel design was erected using 3/4" PVC pipe for arches, attached to a wooden base constructed with 2x8 cedar boards. These two materials were fastened with carriage bolts. PVC piping was used for a stabilizing ridgepole, fastened with binder twine. The end walls were framed with cedar and a door constructed on one end. The end walls and door were covered with carrot rust fly netting. Mid-season, the tunnel design was reinforced with a wooden A-frame to support the PVC arches.

PVC hoops were secured to the frame with carriage bolts, nuts and washers.

The 2x8 cedar frame was secured to the ground with stakes and nails at regular intervals.

The netting and poly are wrapped over the white PVC tubing. Split 1" poly irrigation line slips over the white PVC tubing, securing the plastic and netting it in place.
The end walls and door are covered with netting. The netting around the door tucks into the frame to make a snug fit.

Selection

All the growers participated in two selection processes within the scope of this project. First, the stecklings harvested Fall 2012 for growing in Summer 2013 were selected for desirable traits such as colour, size, disease resistance and flavour. This season, selection occurred on all farms for next year root crops for seed production.

Germination

Seeds were tested for germination rates by a single grower under the tutelage of an experienced silviculture consultant. Germination testing was conducted over 17 days for each variety grown in each region, replicated 4 times for each variety. In one case, field controls were also tested.

Germination chambers were 4” square by 1.5” deep plastic petri dishes. Each chamber was washed in soapy water and a 10% chlorine bleach solution, rinsed well, and air-dried. Each dish was filled with a square of laboratory wipe cut to fit, 2 layers of unbleached filter paper and 40 ml of distilled water. Water was added only when the seeds were counted and ready to load into a dish. One hundred seeds per container were placed so that they were not touching each other. The process of counting out and arranging seeds in the petri dishes required three evenings to complete.

Seeds were incubated with 8 hours of daylight at 30°C and 16 hours of night at 20°C.
Germination chambers were checked for germination approximately every 3 days. Seeds that had germinated and had sprouts 4x the length of the seed were counted as germinated. Seeds that had germinated were removed from the dish and the germination date recorded.

**Temperature**

Temperature graphs were constructed from maximum daily temperatures recorded digitally, within tunnels and in outside environments [Figures 1-4]. When data were unavailable, temperatures were extrapolated based on the maximum temperatures recorded prior to and after the missing data. Relevant dates, including first open flower, addition of pollinators and harvest dates were overlaid over maximum temperature values to create a summary profile for the conditions each variety experienced until harvest.

**Pollination**

As the caged environments deny entry of natural pollinators to the flowering seed crops, pollinators had to be intro-

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**Figure 1:** Maximum daily temperatures in high tunnel and outdoor environments in Johnson’s Landing

![Graph 1](image1)

**Figure 2:** Maximum daily temperatures in high tunnel and outdoor environments in Nanaimo

![Graph 2](image2)
duced by farmers during anthesis, the period of plant flowering. For in-tunnel pollination, two of the growers released Blue Bottle flies (Calliphora vomitoria) from a commercial source, introduced in either pupae or adult stages, in addition to animal carcasses in situ. Two growers cultivated all pollinators using animal carcasses with no commercial pollinator introduction. The in-field crops were pollinated by naturally occurring pollinators. The pollinator supplier recommended that 6 cups of pupae or flies would be adequate for pollination of 1000 ft² of carrots.

**Relative Humidity**

Despite the initial intention to record relative humidity within the tunnel structures, lack of access to hygrometers prevented consistent readings from all but one grower.

**Data Collection**

Data collection was performed by each farmer using standardized forms. Unfortunately, due to the rapid project start-up, standardized forms were not made available to farmers until June, after which high and low temperature in tunnel and outside were recorded, along with pollinator introductions and other observational notes. Responses from farmers were coded to elucidate common threads.

**Spacing**

Spacing of roots varied from 6" to 18". One farmer experimented with spacing one bed 6" apart and a second with 10" spacing. The spacing distances are unknown for one farmer, and no further data was collected on ideal spacing.

**Irrigation**

Irrigation systems were documented in order to record both the effects of adequate watering on plant health and affects on seed quality. Two growers had preexisting drip irrigation, and two others relied on overhead sprinklers and handwatering. In one instance, drip irrigation failed and handwatering was implemented.

**Limitations and Barriers**

As with any farm season, limitations and barriers arose, influencing research methodology and results. The realities of demands on a farm as well as the occurrence of personal life events pulled farmers from the project at times and

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**Figure 3: Maximum daily temperatures in high tunnel and outdoor environments in Lytton**

![Temperature Graph](image_url)
resulted in holes in data collection and ability to perform optimal crop maintenance. Growers adapted to these limitations in various ways, and when possible came up with suitable alternatives and innovations.

Planning phases of the 2013 season morphed quickly into the 2013 growing season. Rather than push the project back a year, the coordinators and farmers went ahead, working together to produce standardized forms as early as possible and setting up regular conference calls for participants to check-in. Another outcome of moving ahead with the 2013 growing season was the disparity in carrot varieties farmers were able to grow out for seed crops. As carrots require roots to be grown out the year previous to producing seed coordination of crop variety was not possible.

Farmers have differential access to materials, in addition to their individual preferences in techniques and tools. Standardized tunnel designs were limited by these factors, though the results from the divergent designs may very well reveal allowable variation of design for recommendations at the projects completion.

Finally, geographic distance between farmers, project coordinators and consultants functioned as a limitation. Project coordinators were able to visit three of the four farms once throughout the season. Though face-to-face communication, on site, is often ideal, the geographic distances dictated that teleconference calls and email be the primary mode of communication.

### Table 2.1 Regional factors and growing conditions for flowering and germination success of varieties

<table>
<thead>
<tr>
<th>Seed Source</th>
<th>Environment</th>
<th>Tunnel Dimensions</th>
<th>Number of Stocklings Planted</th>
<th>First Open Flower</th>
<th>Percent Flowered (%)</th>
<th>Seed Harvest</th>
<th>Germination Rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Johnson’s Landing – West Kootenay</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Nantes Coreless</td>
<td>Stellar Seeds</td>
<td>Tunnel</td>
<td>36’ x 12’</td>
<td>150 on Apr 23</td>
<td>Jul 25</td>
<td>28</td>
<td>Sep 18</td>
</tr>
<tr>
<td><strong>Nanaimo – Central Vancouver Island</strong></td>
<td></td>
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<tr>
<td>Amsterdam Gold</td>
<td>Growing Opportunities Farm</td>
<td>Tunnel</td>
<td>78’ x 6’</td>
<td>198 on Apr 4</td>
<td>Jun 14</td>
<td>95</td>
<td>Sep 9; Sep 20; Sep 29</td>
</tr>
<tr>
<td>Purple Haze</td>
<td>Growing Opportunities Farm</td>
<td>Tunnel</td>
<td>78’ x 6’</td>
<td>163 on Apr 4</td>
<td>n/a</td>
<td>95</td>
<td>Sep 20</td>
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<tr>
<td><strong>Lytton – Fraser Canyon</strong></td>
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<tr>
<td>Burlicummer</td>
<td>Planting Seeds Project</td>
<td>Tunnel</td>
<td>40’ x 20’</td>
<td>380 on Jun 30 and Jul 7</td>
<td>n/a</td>
<td>13</td>
<td>Sep 4, Sep 13, Sep 29</td>
</tr>
<tr>
<td>Purple Dragon</td>
<td>Sudoa Farm</td>
<td>In field</td>
<td>Unknown number on Jul 14</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Sorrento – Shuswap</strong></td>
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<tr>
<td>Nantes Forto</td>
<td>William Dam</td>
<td>Tunnel</td>
<td>45’ x 22’</td>
<td>100 on Apr 11</td>
<td>May 29</td>
<td>100</td>
<td>Late Aug</td>
</tr>
<tr>
<td>Purple Dragon</td>
<td>Sudoa Farm</td>
<td>In field</td>
<td>200 on May 29</td>
<td></td>
<td>95</td>
<td>Sep 25</td>
<td></td>
</tr>
</tbody>
</table>
Research Results and Analysis

Plant Loss
As a seed crop, carrots have the added challenge of susceptibility to plant loss during storage and field conditions. One farmer reported losing a high percentage more plants than was typical, citing poor overwinter storage (not cold enough and too low humidity) as the likely cause. Another lost a high percentage to late planting and high temperatures before plant establishment. Two growers maintained over 95% of their populations after transplanting.

Interestingly, divergence in planting dates didn’t affect greatly the timing of harvest between growers. However, timing of planting possibly affects plant success, as the earliest planting dates saw the least degree of plant loss. This will be interesting to monitor in subsequent years. In addition to late planting dates and inadequate storage conditions, loss to grazing animals was listed as a cause of plant loss.

Temperature
All farmers reported temperatures higher than 35°C in their high tunnels in peak summer months, reaching to highs of 50+°C at one site. At and above 35°C anthesis, the period of plant flowering, is impeded and embryogenesis (development of the seed embryo) can be damaged. Climate control proved difficult during the hottest months. All farmers installed mesh siding on their tunnels in some capacity.

Flowering is the most critical point in carrot seed production. For carrots, we learned, the ideal temperature in the flowering stage is from 27° to low 30°C. Ideal seed maturation temperatures range from 30° to 35°C (Navazio, 2012).

During a group discussion, one grower reported success with evaporative cooling in the greenhouse. Greenhouse temperatures would drop considerably when watering occurred during high temperatures. Other growers reported this information as useful.

Another grower made ventilation windows in both tunnels with carrot seed mid-season in an attempt to bring down high tunnel temperatures. Seeds with more ‘bearding’ (hairs on the seed coat) were noted near the ventilation windows, and umbels near the windows developed before other areas in the tunnel. In addition, the seed colour was noted as being characteristic of quality carrot seed more so than the seed away from ventilation. Germination results indicated that, in one variety, the window seed had significantly higher germination success.

The option of solar-powered fans for the second project year will be explored.

Relative Humidity
Measurements of relative humidity were recorded at only one farm site. Lack of data prevents meaningful consideration of the effects of relative humidity within high tunnel structures for this season.
“Last year, carrot flower perfume was the most enchanting smell! 2013, carrots smell like road kill.”

Carrots, like other Apiaceae crops, require insect pollination for reproduction. Tunnels exclude pollinators from getting in, which is desired for isolation from cross-pollination, but of course requires the introduction of pollinators. True to organic philosophy, a goal for growers was to explore how to create on-farm pollinators without external inputs. While two farmers did end up purchasing Blue bottle fly pupae from a source in Idaho, all four experimented with cultivating their own pollinators. Growing mediums for maggots (i.e. animal carcasses) came from two sources: dinner scraps and the road. Growers reported back on those mediums that worked best for them, as well as shared stories of the awkwardness of collecting roadkill for their tunnels. As one grower stated: “I felt a little more normal when I heard that other carrot seed producers were also scanning the roadsides and collecting roadkill.”

Come flowering time, anecdotes of pollinator experiments flowed in. Since growing within a tunnel creates an ecosystem that effectively denies entry to outside pollinators, maintaining a consistent flow of pollinators inside the tunnel ecosystem proved to be a task that required forethought and a good degree of experiment. Luckily, conference calls between growers shared ideas, techniques, and reassurance. There is no doubt that some of the liveliest conversation of the project came out of each farmer’s personal pollinator regime. Of the check-ins between project participants, one grower wrote:

“[I] seemed to observe the animation of the talk around pollinators especially. Meeting[s] often seemed to be productive, encouraging, bring up topics we all need to be thinking about, supports action... I got over my bear concern, and started collecting grouse roadkill. Having dealt with bears over many years in this field, I did not feel like entering this arena. However, it was a low bear year, and worked out fine.”

Over the course of the season, there were successful experiments:

“My second batch was started with cooked chicken skin/bones/some meat prior to June 9th and proved far more successful, a later batch using a heavily fatted pork roast was VERY successful”

And less successful experiments:

“Maggot soup...I neglected to mention that I had previously put an old chicken carcass in a bucket in the greenhouse, to try and see if flies would lay eggs in it and hatch out maggots, then perpetuate themselves as blue bottle flies, and save me having to order them from Idaho. Well...the greenhouse needed watering, so [our apprentice] set up the sprinkler inside and irrigated. What happened was the bucket filled up with water and I came home to find a soggy, floating chicken carcass as well as a bunch of dead floating maggots.”

Grower reflected on their newfound (and unexpected) hobby of scanning of roadsides:

“And I told my friends. And elicited their help. Thus began the great community cruising for roadkill. First time really that I have looked at roadkill as serendipitous. A useful and happy (and sad) thing. And friends would tell me of times on the road, when they saw a roadkill, and were just a little too late to pull over. Or [they] had a something die, did I want it? ...Just let it be known, that no animals were harmed intentionally in the pursuit of carrot seed production.”

As well as their amusement in cross-border pupae purchases:

“I love living in a modern age...[y]ou can go online, order FLIES, and they will cross the border, and be delivered by mail, to your home. They come in a paper bag. Sort of like things that in the past people were embarrassed about, and covered in plain paper wrappers. You know, like certain magazines used to be in plain paper wrappers.”

Comedy aside, a well-planned and monitored pollinator program is necessary for growing seed in isolation tunnels. For carrot seed, each flowering umbel will ideally have multiple flies at any given time, and pollinator populations will be consistent throughout the course of flowering. Flies also need access to a water source within the tunnel. See the Resources section for a Blue Bottle fly pupae source.
Tunnel Structures

All four tunnel designs differed in their construction, materials used and dimensions. The variations in design perhaps reflect a more accurate reality for farmers in the BC region, and provide an opportunity to evaluate different designs towards the research objective of recommending ideal infrastructure.

One grower had to make amendments once their initial design collapsed under strong winds and damaged the carrot crop. This grower reported that changes to reinforcement of an identical structure on their farm proved more efficient and effective. Instead of their initial wooden A-frame reinforcement they used bent 1/2" rebar fit into PVC piping installed alongside the original PVC-only arches.

Greenhouse poly plastic on all four tunnel designs was certainly a major contributor to high tunnel temperatures. One grower reported previously constructing remay cloth tunnels to isolate carrot seed crops, which resulted in lower in-tunnel temperatures. However, remay tunnels do not provide easy access to the growing seed crop, and while they may prove to be more effective in avoiding pollen-damaging high temperatures, they do not offer the season extension qualities afforded by the partial use of greenhouse poly. Protecting maturing seed from autumn rainfall, for example, is a real necessity for BC growers, especially in coastal and Kootenay regions.

All growers reported exceedingly high temperatures in their tunnel designs, and three reported that more venting alongside fans would be experimented with in the second season.

Pollinator Introduction

Pollinator populations were maintained in two ways for this project. At two sites where purchased pollinators were introduced, pollinators were released as the growers noted that the first flowers were imminent. Blue Bottle flies were purchased as they are adapted to work in small areas, are effective pollinators, and can be shipped as dormant pupae (see Further Resources). Consistent pollinator activity was an issue for two of the farms. One found that the commercial pupae could be held in suspended animation in the refrigerator and released in smaller amounts at more regular intervals. The commercial flies purchased by another grower arrived in adult stage and had to be released en masse.

Both the growers that purchased pollinators left a growing medium in the tunnel for fly cultivation.

The remaining two farms cultivated all pollinators on-site and reported generally consistent and high pollinator activity in their tunnels. One grower experimented with varying pollinator-growing mediums. They recorded pig liver as the least successful, postulating that this may be due to little to no fat on the organ. Next, a cooked chicken carcass and then a fatty pork roast were used, the latter being the most successful. The growing mediums were placed in a bucket and left exposed to natural pollinators, and then left in the sealed tunnel environment.

Pig heart, salmon carcass and grouse carcass were also used with good success. [See text box 4].

Irrigation

One grower recorded that their overhead-watering regime would be replaced by drip irrigation in subsequent years. Excessive seed moisture and blackening of seed heads were noted. Additionally, overhead watering caused plants to fall over in some cases.
Pollination Success

Two of the farmers reported significant numbers of umbels with sporadic development of mature seed. Temperatures at all farms reached above the recommended 35°C during flowering, running the risk of impeding the release of pollen as well as development of the seed embryo. While high temperatures were certainly taken into consideration, one participant reported that uneven fertilization on many umbels indicated to them inadequate pollination as a more likely culprit. As this grower was able to grow their carrot seed out in the field in their previous location, they noted significantly fewer insects on the carrot crop within the tunnel environment this season. This grower noted a large amount of the introduced fly population situated on the wooden posts of the tunnel and not on the plentiful umbels in flower. In conversation with a project consultant, it was suggested that the flies were likely lethargic due to the high tunnel temperatures. It was recommended to supply the flies with a constant source of water in addition to attempts to lower high temperatures.

Pests and Pathogens

Pests and pathogens are to be expected to some degree in greenhouse and other caged environments, and in particular in isolation tunnels where general insect access is denied. While there are certain benefits to creating such an environment, they are often not balanced ecological systems. One grower noted a significant aphid population, worse than what they would typically see in the field, in the presence of natural aphid predators.

In one instance, a farmer expressed worry about the carrot pathogen Aster yellows phytoplasma (AYP) present in their crop. Sharing these concerns with the group prompted another grower to inquire when the plants had been last fed nitrogen, required for vigorous, green plants. The carrots, which were planted later than optimal, did in fact need fertilizing and responded to feedings of fish fertilizer.

Two growers experienced whitefly infestations in their tunnel environments. Significant whitefly populations can damage seed crops, and can be maintained in a number of ways. In this initial year, one grower expressed that they had not been able to initially identify what was causing widespread damage to the umbels of their crop, and only later through sharing data did they realize it was a whitefly infestation. This knowledge provides information for more proactive integrated pest management in the future.

Another grower experienced considerable spider mite damage to umbels, and utilized safer soap in an attempt to halt the population, with good success.

Other common pests for carrots include Carrot Rust Fly (Psila rosae), which can damage roots for seed, and Lygus. spp., which feed on the embryo of developing seed (OSA, 2010b). Neither of the above pests were noted by farmers this season, though it was noted that precautions against rust fly damage (using mesh row cover) on market and first-year roots need to be taken.

Participant Satisfaction

Though not initially included as measurable piece of data, participants in the inaugural project year reported significantly on the experience of the farmer-led model. Appreciation of the multidisciplinary, participatory approach was repeatedly expressed. The shared experimental spirit of the project, the financial compensation for all participants, and the exponential learning born out of
sharing of experiences were all listed as positive outcomes. Working with the project consultants built relationships across provincial and national borders that broadened the network committed to localized seed sovereignty.

An important component of the participatory process was regular conference check-ins and debriefs with project participants. The term ‘little learnings’ came up repeatedly, pointing to the composite nature of on-farm knowledge.

By no means complete, subsequent years will strive to report on the little learnings that come out of this type of work, as well as the larger strides made in increasing the regions access to quantity and quality of carrot seed.

**Germination**

Six varieties were grown in this project. One variety, Purple Dragon, was grown at two different sites. Of the seven plantings, six of were tested for germination rates [see Figures 4 & 5]. The seventh planting did not make it to seed set because of plant loss due to livestock.
Three of the four growers utilized empty space in their high tunnel for intercropping with multiple crops. Multiple crops can be incorporated into the tunnel design to maximize space, isolate multiple seed crops at once, and encourage beneficial companion growing.

As seed crops produce plentiful flowers, they foster biodiversity in the organic farming system by attracting pollinators and providing insects with nectar and pollen. Intercropping points to a way that vegetable growers might begin to incorporate seed production into their operations while still maintaining space for market crops. For example, fast growing crops such as lettuce or cilantro might be well suited to growing near slower-to-mature seed crops.

On the trip to Washington, we visited a seed isolation tent that housed both carrot seed and kale seed crops. Planting the two crops together maximized the use of the expensive mesh infrastructure.

Companion planting is frequently used in organic systems, serving a host of functions including promotion of pollinators and beneficial insects, habitat creation, pest management and increased on-farm biodiversity. Pest management is especially relevant for growing in high tunnels, where natural balances of insect populations are often lacking. During conference calls, two growers lamented significant whitefly infestations in their tunnel environment—a small insect that can cause big damage to carrot umbels. It was suggested that growers consider planting Shoofly plant (Nicandra physalodes) alongside their carrot plants next year as a pest management strategy.

Another grower had issues with aphids in their tunnels. While pollinators of carrot flowers require introduction into the enclosed tunnel environment, aphids do not need to be introduced—a fact that became very evident to this particular grower. In such a case, intercropping with plants that attract and provide good habitat for ladybugs (a natural predator of aphids) would be a useful pest management strategy. Of course, intercropping may not be enough as beneficial insects, such as ladybugs, may also require introduction to tunnel ecosystem.

A lesson that came to one grower out of experimenting with intercropping multiple seed crops in their tunnel was that plants need room to grow and spread—especially in the high heat tunnel environment. The experiment had been to plant cucumber plants, also requiring isolation for seed production from field varieties, in the spaces where carrot plants had been unsuccessful. As the cucumbers thrived in the hot tunnel, they towered over the carrot plants, blocking out sunlight and decreasing airflow around the developing seed heads. That said, the cucumbers were a good measure of pollination success early on, as the plants became laden with many small (and then big) fruits. The lesson for the grower here was that intercropping might be best achieved in the high tunnel environment through separating seed crops within the tunnel and allowing each crop the adequate spacing it needs at maturity for air flow and sunlight.

**Text box 5: Intercropping in High Tunnels**

Potatoes (L) and nasturiums (R) interplanted with seed carrots within the tunnel
Summary of Findings from the 2013 Season

This project exemplifies the potential in farmer-led projects in British Columbia. The four farmer participants brought their own histories and skills in seed growing, plant breeding, community-based research and knowledge mobilization. Farmers directly participated in funding applications, blog posts, conference presentations, data analysis and project reporting. Project participants reflected a high interest in continuing for future seasons.

The primary long-term objective of this project is to determine the ideal infrastructure for growing carrot seed in isolation tunnels. To this end, the data collected from this season’s growers provides only preliminary insight. Ongoing research will be required to realistically achieve this objective, taking into account the balance between producing high quality seed in quantity while maintaining economic viability. Similarly, the second objective to provide cross-regional analysis and share findings with the regional seed growing community will require that more specific regional climatic data be recorded and analyzed. Dissemination of materials to the wider seed growing community will continue to be a priority in subsequent years.

Grower comments and recommendations for subsequent years were plentiful. One of the resounding reflections on the project from all participants has been the positive experience of working on a farmer-led, participatory research project. The benefit to farmers in working in a collaborative model was repeatedly underscored, as ideas and concerns were shared.

The findings in this initial year point to improvements to research methodology, temperature control, inclusion of seed weight as a marker of seed quality, and the need for regular intervals of pollinator introduction.

1) Future improvements to research design.

The regional distribution of these trials provides coverage of productive areas of British Columbia for carrot production. Non-standardized trials across these regions cannot provide conclusive insight into the ideal infrastructure of tunnels for carrot seed production. In coming years, methodology could be standardized by providing farmers with varieties from the same seed stock, providing an in-field control trial for every variety grown within a tunnel, and standardizing, as much as it is possible, the high tunnel structures themselves.

Participating farmers could also seek to streamline and standardize the type of data recorded for each trial. Consistency in the approach to research methodology will greatly improve upon the project’s ability to recommend best practices in tunnel seed production within and across regions. In group debriefing sessions, it was general consensus that improvements to recording similar measures and records of temperature and relative humidity; dates of planting, germination, first flower, and seed harvest; the number of plants flowered; and total number of seeds harvested could provide a clearer indication of the effectiveness for carrot seed production.

Finally, temperatures could be recorded from date of planting so as to provide a comprehensive record of the process from planting to seed harvest.

2) Standardize key aspects of high tunnel design.

The ability to regulate the climate inside tunnels to avoid temperatures over 35°C during the flowering stage was a concern for all farmers. Future tunnel designs will necessarily need to address this issue, either by redressing the tunnel design to include adequate screen mesh, or investing in solar-powered fans. Both these
options require farmers, who already typically operate on tight budgets, to invest in these technologies. To this end, a thorough financial analysis of high tunnel construction would also be useful.

Key aspects of tunnel design to be standardized should include, as much as possible, building materials, irrigation, polllination regime, and soil amendments.

3) Include seed weight as a measure of quality.

In order to determine ideal infrastructure for carrot seed production, measures of seed quality could extend beyond germination testing to include seed weight, a common indicator of seed quality.

4) Regular introduction of pollinators and/or growing medium.

Standardizing pollinator introduction techniques would also allow for discerning specific benefits that tunnel cultivation offers and avoid scattered pollination. Growers noted about a week lifespan for their fly populations, suggesting that weekly introductions would be ideal if using a commercial source of fly pupae. From the onset, growers should leave standing water for pollinators to drink, monitoring pollinator activity especially when temperatures are high.

Conclusions

Based on current expert opinion and industry standard, results are encouraging.

This research is a coalescence of decades of foundational work by seed growers in the region and beyond. It builds on the efforts of many past projects and initiatives, and adds to this knowledge by encouraging a process by which farmers can undertake ongoing participatory research. This research model, with farmers as key participants who shape research objectives, simultaneously deepens the knowledge and skills of participating seed growers in a way that promotes a more secure regional seed system.

Based on current expert opinion and industry standards, germination results in this first year are encouraging. There is certainly preliminary evidence that quality carrot seed can be grown within high tunnel environments, and subsequent years will point to variables that influence seed quality as well as quantity. As this project grows, so too will the availability of regionally adapted carrot seed varieties.

As a final thought, a central tenet of the seed saving movement has been the sharing and trading of varieties. Throughout the season, many stories were shared tracing the genealogy of certain carrot seed, including two varieties grown out by farmers this season. As one participant reflected, “the story goes with the seed.” Indeed, the carrot seed grown this season weaves yet another story into the landscape of regional seed security in BC.
References


Further Resources

http://www.farmfolkcityfolk.ca
http://www.seedsecurity.ca/en/
http://www.seedsecurity.ca/fr
http://www.seeds.ca/bauta/seedfinder.php
http://www.seedalliance.org
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