Challenges and Opportunities with Seed Production in Enclosures

Chris Thoreau, Bauta Family Initiative on Canadian Seed Security and FarmFolk CityFolk; Jen Cody, Growing Opportunities Farm Community Coop; Shaina Bronstein, Vitalis Organic Seeds; and Laurie McKenzie, Organic Seed Alliance

Correspondence: laurie@seedalliance.org

Seed is most often produced in the expansive outdoor environment. However, structures such as greenhouses and mesh tents can be used as isolation structures for research, breeding, variety segregation, and environmental control of seed crops. Caged seed production using isolation structures presents several challenges and fun opportunities, including choosing structure design, set-up and maintenance, pest and pollinator control, and economic considerations.

Research in Enclosures

Isolation structures are extremely valuable research tools. Screened net cages and mesh bags are used to ensure pollinator exclusion and controlled pollen exchange for many types of crosses and seed increases, including multiplication and production of inbred parent lines, single plant crosses, strain crosses, self-pollinations, and increasing open-pollinated varieties and breeding populations. Multiple unique lines of the same or compatible species crops may be planted in the open field and isolated by means of covering plants with netting or cages before flowering occurs. This method is most appropriate for insect-pollinated, cross-pollinating crops with the introduction of pollinators, such as bees or flies. Although caged seed production is possible for wind pollinated crops, it is significantly more challenging compared to insect pollinated crops, as the density of mesh required to contain pollen restricts both light and air flow.

In British Columbia, small-scale farmers are currently engaged in a participatory research project with the University of Manitoba, FarmFolk CityFolk, and the Bauta Family Initiative on Canadian Seed Security to explore the use of isolation structures for growing carrot (*Daucus carota*) seed. While carrot seed crops perform well in BC’s coastal climate, the overwhelming presence of Queens Anne’s lace (*Daucus carota* var. *carota*), which readily cross-pollinates with domesticated carrots, makes carrot seed production extremely difficult. This research project is exploring several aspects of caged seed production, including crop population management, pollinator rearing and management, and economic analysis for small-scale carrot seed production.

In Washington State, Organic Seed Alliance (OSA) is also challenged by the ubiquitous presence of Queen Anne’s lace in their endeavors to produce carrot seed as part of the CIOA (Carrot Improvement for Organic Agriculture) project, which is funded by USDA’s Organic Research and Extension Initiative (OREI). OSA is using cages to make unique and new populations of carrots for breeding work, growing out selections to further breeding populations currently under development, and to increase seed of desirable populations to make them available for national trialing efforts. Experimenting with a range of small cage sizes from 25 to 200 square feet, OSA has also done multiple species seed production, combining Brassica and flower production in the same cages with carrots.
Structure Designs and Considerations

Cages can vary greatly in size depending on the scale of your operation, typically ranging from several to thousands of square feet. Cages can also host multiple crop species within a single cage as long as they are not biologically compatible. Cage design and integrity can be crucial to the success of your seed production efforts. There are very few companies that produce pollination structures and thus they are often made on the farm. One reliable source for pre-fabricated cages is Redwood Empire Awning (http://www.redwoodempireawning.com/agricultural-projects/), a company that manufactures custom pollination cages to fit your specific needs. The kind of mesh used for cage construction must be able to exclude any kind of pollinating insect, as well as contain any pollinators introduced into the cage. A 20x20 mesh is needed to exclude flies and bees, while a 52x52 mesh is required to exclude aphids. When choosing a cage cover or netting it is important to consider what pollinators you will want to use (flies, bees, bumblebees), as well as any beneficial insects you might want to contain over the course of the season.

Mesh cage fabrics also come in different colors, most commonly green and tan. There has been some speculation that tan cages do not heat up as quickly as the darker colored green mesh cages and hence provide a cooler atmosphere, which is an especially important consideration if bees are going to be used inside the cage.

Cages are commonly built in two design styles – rectangular and quonset. The quonset style cage design has less wear points since it has fewer hard angles and is therefore more durable from season to season. In areas of high wind or when cages are expected to last multiple seasons, it is recommended to use a quonset style cage to increase cage longevity. With a quonset style cage, there is a sacrifice of some walkable space within the cage due to the side-wall angles, so if you are growing tall flowering crops or plan on monitoring or roguing your crop extensively throughout the flowering and fruiting period, you may want to consider a rectangular design.

Cage integrity is critical to keeping your seed increase(s) pure. The introduction of only a few outside pollen sources via insect can contaminate your entire production with no noticeable effects until the next generation is grown out. Cages need to be accessed throughout the growing season for monitoring the crop and pollinators; roguing the line, variety, or population; and for cultivating, fertilizing, pest control, and any other additional crop maintenance. It is prudent to include two entrances in your cage design, one on each end, especially if using a zippered entryway. The reason for this is that if one zipper fails, you can seal off that entrance while still having another convenient entrance for accessing the cage. The faster you can enter and exit the cage, the less chance you have of inadvertently introducing unwanted pollen sources or allowing insects to fly in or out. For this reason, a zippered entryway is recommended over a folded and fastened approach. While the zipper is often one of the first places to
fail on a cage, it is a nice convenience throughout the course of a season. It is prudent to double stitch and reinforce zippers and seams during initial cage construction to lessen the chance of tears and splitting down the road.

The bottom edges of the cage netting should be substantial (I recommend a minimum of 2 feet) to allow for securing/burying the edges beneath the soil. If cage bottoms fly up, the integrity of your seed production can be ruined in a very short period of time. Points of wear, such as corners and bottom edges, can be reinforced with heavy duty vinyl to ensure they stand up to the wear and tear of use over multiple seasons. Lastly, cages should be inspected at erection as well as regularly throughout the season to ensure that any holes that develop in the mesh netting are immediately repaired. Holes can be mended with a sewing needle and thread and extra mesh fabric, or in a pinch with heavy duty duct tape. I have found a heavy-duty, curved needle is especially useful for this task.

Single plant crosses or single plant self-pollinations can be achieved in much the same way as caged seed production, only on a smaller scale. “Bagged” cage increases involve caging only one or two plants in order to make a specific cross or a self-pollination. In this instance, species that are amenable to natural self-pollination or those that employ fly pollination are most appropriate. Typically, wooden or bamboo stakes are driven into the soil next to the plant and used to secure a mesh bag around the plant’s flowering parts. Fly larvae can be added by untying the bags and allowing the flies to crawl up out of their container and into the pollination bag. Pollination bags can be removed once flowering is complete to allow for unhindered development of the seed crop.

Pollinators for Enclosed Structures

Pollinator management in isolation cages is critical to ensuring effective pollination and subsequent seed set. Cross-pollinated crops often rely on insects for pollination, thus insects will need to be introduced to the isolation structure to ensure pollination takes place. While bees are often the first insects that come to mind when one thinks of pollinators, flies are also very good pollinators and are easy to rear and maintain.

Bees as Pollinators

Using honeybees can be challenging, expensive, and hazardous in small cages. Even in larger cages, the stress to honeybees causes high mortality as they need ample pollen and nectar to stay healthy. Nuke hives (small starter hives) are generally best for caged pollination and it is recommended to work with a beekeeper to place them within your cage(s). It is best to keep the bees in the cage only as long as necessary for the pollination of the crop as it is somewhat stressful for a hive of bees to have only a single floral food source. To this end, careful observation should be employed to determine the convergence of the opening of female flowers and the availability of pollen from the male flowers. The more time a pollinator is in the cage, the less healthy and less productive they become. It is best to enter cages in the morning or early evening when the bees are least active to minimize the risk of being stung or disturbing pollination activity.

On the other hand, bumblebees are excellent pollinators for caged production and are not as vulnerable as a colony of honeybees. They are especially effective in cages with large flowered crops such as squash. Even so, protective clothing is recommended. Bumblebees will defend their hive and sting...
when in a confined area. You should also consider the possibility of imported viruses affecting native bee populations before using bumblebees in your area.

Bumblebees are smart and are very adept at escaping the enclosure. Fortunately, if Queen Anne’s lace is not flowering and there are no other carrot seed crops nearby, you can open the enclosure in the evening to let the bumblebees back into the enclosure when they return to their hive. If you are early to the enclosure, as the bumblebees are starting to be active, you can assess the enclosure for bee escape routes, and correct the issue. Bumblebee hives are expensive (over $200/hive) and our experience in BC is that the pollination from bumblebees was also not as effective as flies.

**Flies as Pollinators**

Flies are effective pollinators in cages and can be purchased as pupae (see [http://forkedtreeranch.com/](http://forkedtreeranch.com/)) or reared on site. Purchasing fly pupae multiple times throughout the season can become expensive and in Canada particularly can be challenging as pupae are shipped from the US and sometimes hatch en route. From our experience in BC, rearing flies on site is easy and involves just a few steps:

1. Begin fly rearing 2-3 weeks before pollinators will be needed to have sufficient time for flies to complete their lifecycle and build up an abundant population in the enclosure for complete pollination at the time of flowering.

2. Set out a clear tote with a lid on it containing a few inches of soil in the bottom with some fresh meat sitting on top (the smellier the better). The meat attracts flies that will then lay eggs directly on the meat. Drill holes in the tote to allow flies to get into the bin and the hatched maggots to get out and pupate in the soil once the bin is moved into the pollination enclosure. Place the bin in an outdoor location where fly populations are high, such as close to compost piles or standing water. Flies are less active on colder days and may not easily be attracted to the meat if the weather is cool. Leave the meat sit out for several hours and monitor for fly activity.

3. Once the meat has been adequately populated with eggs, move the tote into the enclosure and remove the lid. Any flies trapped in the tote are available to begin pollinating immediately, while the maggots (larva) will move into the soil below the tote or within the tote to pupate. Be sure you don’t have any compatible wild relative plants flowering nearby or have any compatible flowering crops on your farm if you are going to be moving wild captured flies into your cages. Depending on how long the tote was set out for fly capture and how much egg laying activity there was flies should begin to emerge within a week or so. Step 1...
should be repeated in one-week intervals for one to two more weeks, adding the egg populated meat to the cage once a week.

4. Once flies start to emerge they need to be sustained with a reliable source of water. You can achieve this by placing the lid of the tote under a drip line in an “empty” spot within the enclosure (we placed it where our carrot stecklings did not emerge). Place small piles of rocks in the lid to give the flies a safe place to land and access the water.

This method of fly rearing proved to be very effective for carrot seed growers in BC in 2017, producing an impressive population of flies which was sustained throughout the flowering period of the crop.

**Economics of Small-Scale Seed Production in Isolation Structures**

At all scales of production, it is important to consider both the cost of the enclosure and required setup and maintenance time when determining the production costs of a seed crop. For example, carrot seed production in an enclosure at the UBC Farm in 2017 had the following costs: prefabricated 10’ x 20’ structure (from Redwood Empire Awning); the total cost of the enclosure — when amortized over 20 years (assumed lifetime of the cage) — was $298.00/year. The cost of producing the seed crop (including seed conditioning) in this 200-square foot space was $209.00, for a total production cost of $507.00. This production yielded 2000g (4.5 lbs.) of seed from 72 carrot stecklings at 18” spacing. Total labor hours for this crop was between 12-14 hours.

The value of this crop on the market will depend on the producer’s ability to market and sell the crop, or on pre-arranged production contract(s). Calculating the approximate sale of this seed crop at two different price points gives this crop a top market value of approximately $965, and if sold at wholesale prices, as low as $370. Therefore, we have found that the use of isolation structures for economically viable small-scale seed production may be contingent on the producer’s ability to sell the seed at market price(s) rather than at a wholesale price.