On-Farm Carrot Storage Trials, Winter 2012-2013

In response to increasing demand for local vegetables through the winter months, growers are expanding their production of root vegetables for winter storage. With that growth has come a corresponding increase in the need for storage facilities. Some growers are choosing to invest in well-insulated, temperature and humidity-controlled storage chambers, while others are converting existing facilities (such as walk-in coolers) to long-term storage use, or utilizing ambient air root cellars.

Optimal storage conditions are known for most crops, but creating a facility that provides ideal conditions can require a large up-front or long-term investment. Less well-studied is how crops store under less than ideal conditions, and what trade-offs exist between crop quality and storage facility expense.

We used Bolero carrots grown at the UMass Research Farm as a model crop to examine how conditions at four on-farm storages affected carrot quality through the winter months. While these case studies cannot fully address the question of trade-offs between quality and cost, they do offer insight into how different storages affect quality and marketability.

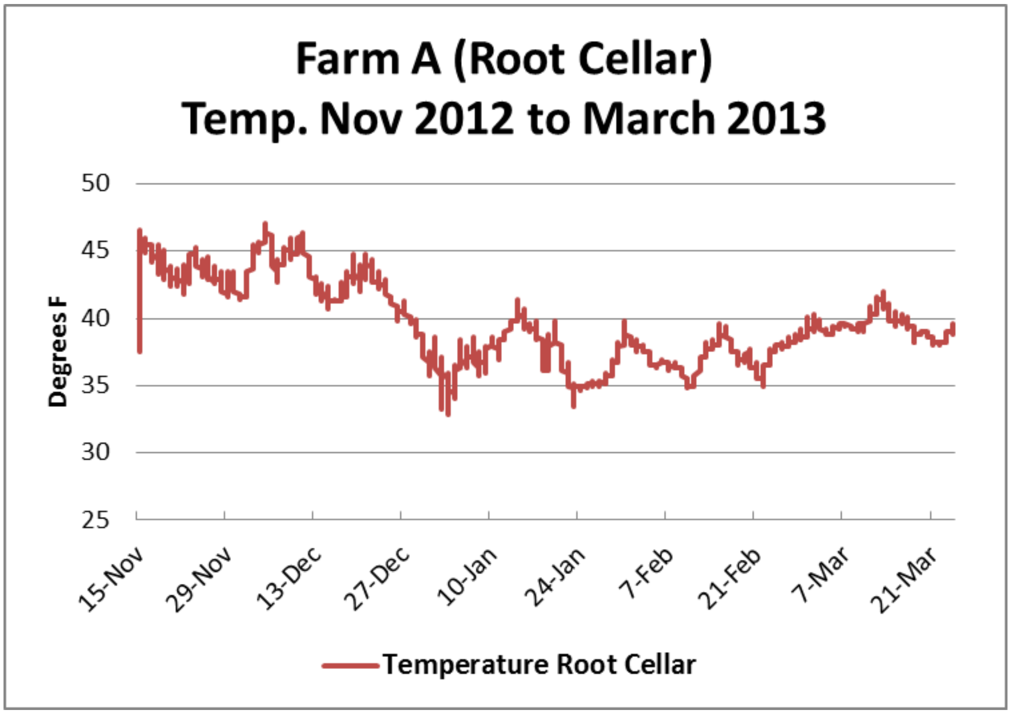
Methods

We fertilized with 100 lbs of chicken manure and 50 lbs of K Mag for two 290' double rows on July 9. We seeded Bolero carrots on July 11, 2012 at a rate of 10 seeds per foot. We weeded and thinned carrots in the week of July 30, and weeded again in the week of August 6. Trickle irrigation was applied as needed.

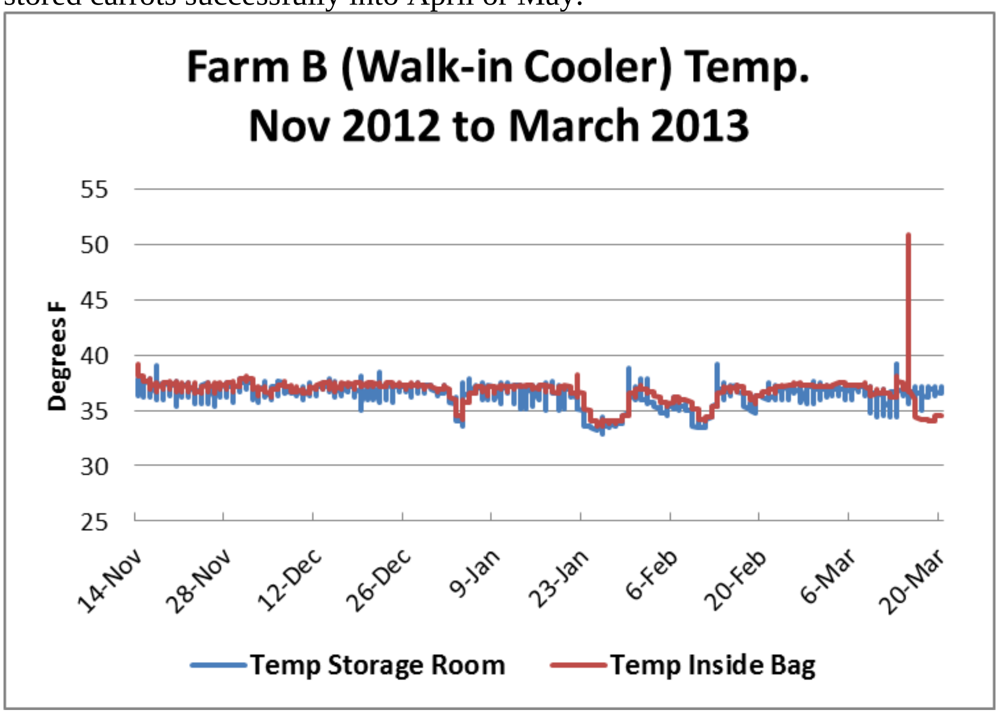
We harvested carrots on November 13 and 14, and topped them in the field. We selected farmer's market-quality carrots free of nicks, scars, or rot. Carrots were placed in the storage facilities the day of harvest, or kept overnight in Bowditch cold storage and placed the next day. Carrots were processed to mimic how carrots were stored on the farm at which they were placed. They were either stored unwashed or were barrel-washed pre-storage. If carrots were stored loose at a farm, we placed ours in 5 lb mesh bags to distinguish them from other carrots, while keeping them open to ambient temperature and humidity, If carrots were stored in perforated plastic at a farm, we placed ours 10 to a bag in perforated plastic bags. We removed one set of bags from the storage each month to sample water loss, Brix score (a measure of sugar content), rubberiness, rot, and other measures of carrot quality. We also brought carrots from on-farm storages to the Amherst farmer's market in January, February, and March. We asked attendees to sample slices of each carrot and rate the carrots based on texture, taste, and appearance. Carrots were rated on a 1-5 scale, with 1 being poor and 5 being excellent.

Farm Storage Facilities

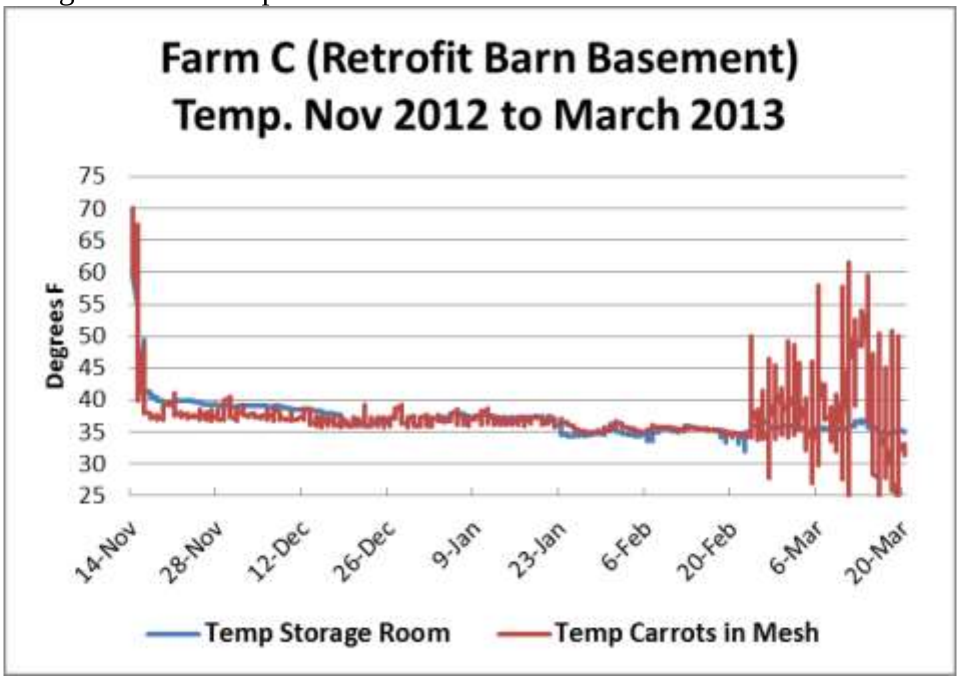
Farm A: Brookfield Farm has a 1300 sq ft root cellar, built specifically for storage. The storage is built underground, with cement walls, 4 in of spray foam insulation, and a standard storm door. Active cooling with ambient air is provided in the form of an 8" pipe with intake/exhaust fan, as well as passive cooling using PVC pipes built into the walls and through gaps around the elevator shaft in one corner. This storage takes longer to reach storage temperatures below 38F than storages using active cooling. Carrots are stored unwashed in plastic bulk grain sacks. Humidity is provided by respiration of stored vegetables, supplemented as needed by wetting the floor.



Farm B: Simple Gifts Farm has a 8' x 8' x 10' tall walk-in cooler. It is a hard-wired three-phase unit, with a compressor, condenser, and fans. Insulation consists of standard refrigeration panels and foamboard in the floor. The farm recently installed a new Cool-Trol system and fans, which allows the system to be more efficient and shut off when not needed. The storage is kept at 38F year-round. Humidity is not actively maintained, but water from wet greens soaks into the plywood floor and keeps the storage quite humid. Carrots are barrel-washed and stored in 25 lb perforated bags. In previous years, the farm has sometimes been able to stored carrots successfully into April or May.



Farm C: Red Fire Farm has a chamber 21' x 47 ' x ~7' tall, insulated with 4+ inches of spray foam insulation inside the walls and ceiling. All chambers are heated and cooled by a geothermal system and cold air from outside. The upper chambers are standard cooler panels. There is a thermostat in the room, but no active monitoring or logging of storage conditions. The chamber is cooled by a geothermal system set to reduce temperatures to 35 F in the winter. Carrots are stored unwashed in large macro 34 vented bins. The carrots are misted to increase humidity, and shrink-wrapped or simply covered on top with a layer of plastic. Open airflow is allowed through the bottom of the pallet. At the end of the season, carrots were moved between storages, along with their temperature sensor.



Farm D: Tangerini's Spring Street Farm has a 320 sq ft space built for high moisture, low temperature storage. The storage is insulated on the roof with foam insulation, flanked by two other coolers, and the back side is insulated by the earth. The cooler is a low velocity unit cooler run on hard-wired electricity. An automated spray system kicks in when the humidity falls too low. Temperatures were monitored with Hobo dataloggers, in this storage, the adjacent squash storage, and outdoors over the course of the winter (See Figure 1). While outdoor T fluctuated, and ranged from upper fifties to below 10ºF, root storage T ranged from 31 to 36 ºF.

Carrots were washed then packed in 25# capacity, perforated plastic bags and then place in either Macro bins or pallets. However, the farm has also considered storing washed carrots loose in large bins. At this farm we therefore performed one trial each of perforated and mesh bags. Perforated and mesh bags of carrots were placed on top of or nestled in pallets containing carrots bagged in perforated plastic. Temperatures in the mesh bags were lower at some periods than in plastic, and fluctuated less in the bags than in the open air of the storage.

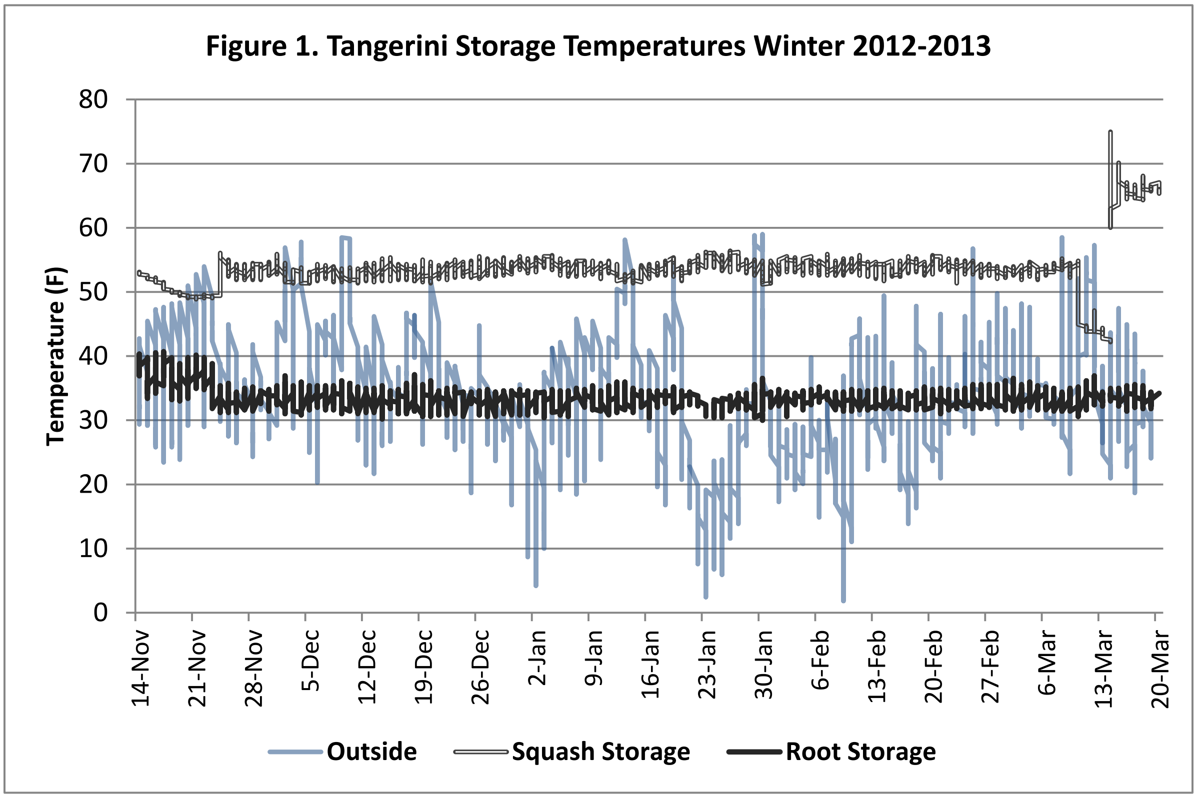


Figure 1. Tangerini Storage Temperatures Winter 2012-2013
Temperature (F)
0
10
20
30
40
50
60
70
80
14-Nov
21-Nov
28-Nov
5-Dec
12-Dec
19-Dec
26-Dec
2-Jan
9-Jan
16-Jan
23-Jan
30-Jan
6-Feb
13-Feb
20-Feb
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6-Mar
13-Mar
20-Mar
Outside
Squash Storage
Root Storage

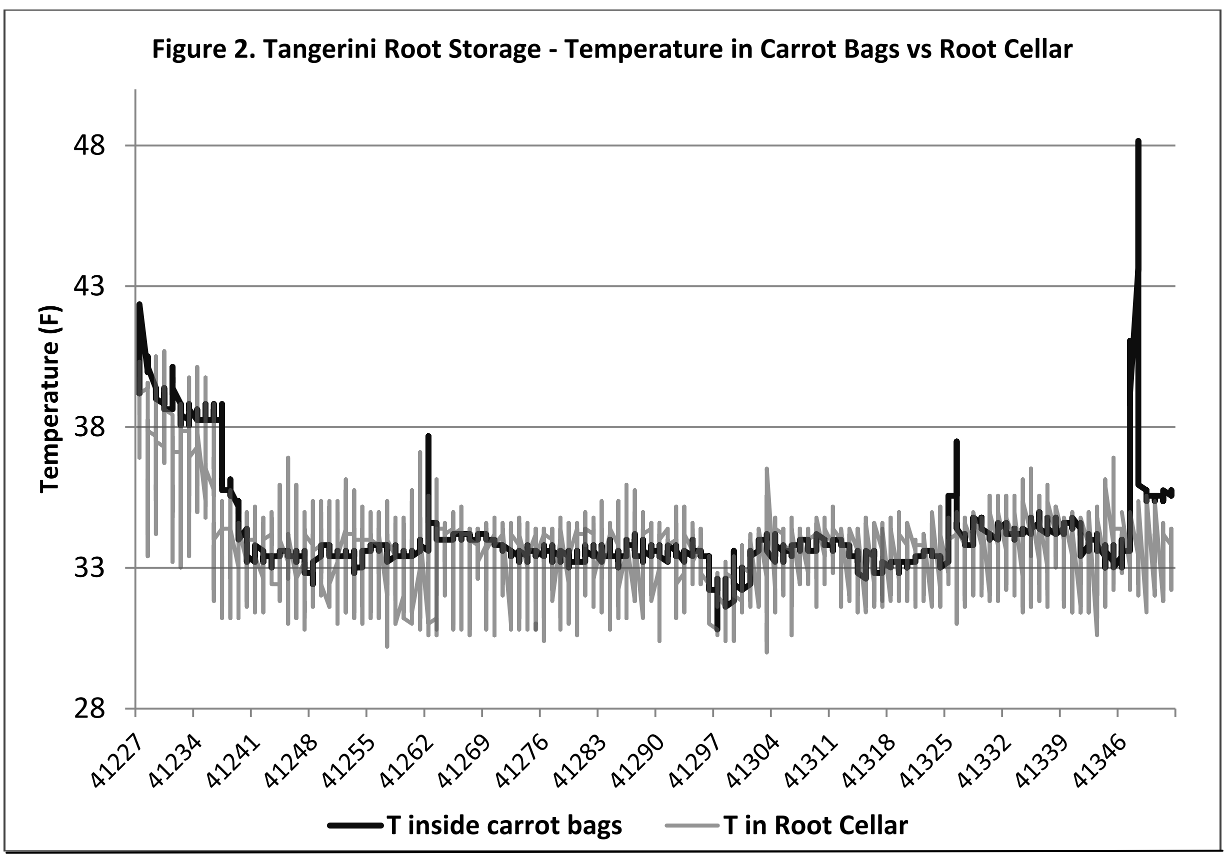
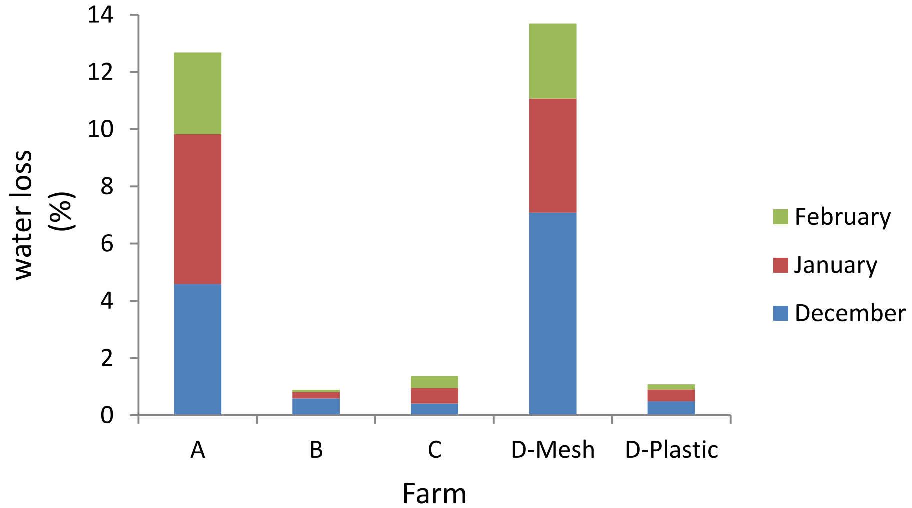


Figure 2. Tangerini Root Storage - Temperature in Carrot Bags vs Root Cellar
Temperature (F)
28
33
38
43
48
41227
41234
41241
41248
41255
41262
41269
41276
41283
41290
41297
41304
41311
41318
41325
41332
41339
41346
T inside carrot bags
T in Root Cellar

Results

Water loss – As we expected, water loss from carrots stored in a root cellar was significantly higher than those stored under the temperature-controlled conditions present in the other three storage facilities. Water loss in root cellar carrots that depend on ambient air (Farm A), which averaged 13% over the first three months of storage, as compared to less than 2% in other locations. What was surprising, however, was that water loss was also very high for carrots stored in mesh at Farm D in the temperature and humidity-controlled chamber (see figure below). While carrots stored under these conditions in perforated plastic experienced only 1% water loss, the greater air flow allowed by mesh bags contributed to a greater than 13% water loss in these carrots, under supposedly "ideal" conditions.



Rubberiness – Carrots that experience water loss tend to become rubbery; carrots stored in mesh at Farm D, and carrots stored in the root cellar, had significantly higher levels of rubberiness than the other carrots. For the carrots stored in mesh, this was evident from the first sampling period in December; for the root cellar carrots, rubberiness was higher in January and February, two and three months after the carrots were placed into storage. The majority of carrots stored in mesh at Farm D were sufficiently bendy as to be deemed unmarketable; by February, 80% of these carrots were considered not suitable for sale.

Sugar content – We found Brix scores to be higher in the carrots that experienced greater water loss, likely due to the fact that loss of water meant sugars were concentrated in the water that remained. Farm D carrots stored in mesh had the highest Brix scores, followed by carrots stored in the root cellar. Carrots stored in perforated plastic at Farm D had the lowest Brix scores.

Marketability – Taste test preferences varied considerably over the course of the storage trial period. In January, after two months of storage, the carrots stored under the closest to ideal conditions – at Farm C and at Farm D in plastic – were the clear favorites, rated significantly higher in terms of appearance and flavor. They also received the highest ratings for texture. 78% and 82% of respondents said they would buy carrots from Farm C and Farm D (plastic), respectively. By contrast, carrots stored in mesh at Farm D and carrots from the root cellar at Farm A received lower scores on appearance, flavor, and texture, and 64% and 58% of respondents said they would buy carrots from Farms C and D (mesh) respectively.

In February, carrots that had experienced water loss again fell to the bottom of the pile in terms of appearance, with Farms A and D (mesh) carrots receiving the lowest scores, and Farm C receiving the highest. We found no significant differences in taste or texture – anecdotally, some people appreciated the crunch and crispness of the carrots that had been stored under ideal conditions, while others noticed the sweetness of the carrots that had experienced greater water loss.

By March, results altered such that carrots that had experienced greater water loss were receiving the highest scores in flavor and texture, with no difference in appearance noted. It appears that at this late date, carrots with a high sugar content were more marketable than those that were well-preserved. 96% of respondents said they would buy the carrots that had been stored in the root cellar.

Discussion & Conclusions

Reducing air flow is very important in maintaining humidity. We were surprised to find that when carrots were exposed to the open air under ideal temperature and humidity, they experienced very high water loss. While some air flow is necessary (slits in bins, or perforated plastic bags) to reduce rot, it is important to keep that air flow low or carrots will dry out. At the tail end of the sample period – in late March – we began to see a low level of rot in carrots stored in perforated plastic, as well as a low level of top sprouting, which is indicative of the carrots becoming biologically active (and less edible). Keeping T steady, and close to freezing may be key to reducing this effect.

Storing carrots under ideal conditions does a great job of keeping carrots from water loss, and maintaining crunch. A simple solution, like a walk-in cooler, reduced water loss as well as a specially designed facility as long as packaging of the carrots is adequate. Marketability was maintained in all storages, even under less than ideal conditions. Protecting carrots from water loss was important, but some water loss appears to be tolerable and in fact lead to sweeter carrots over time. At late season markets, when storage carrots kept under ideal conditions may be tasting flavorless and woody, some degree of softness and sweetness appears to be preferred. However, too much water loss can render carrots unmarketable.

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