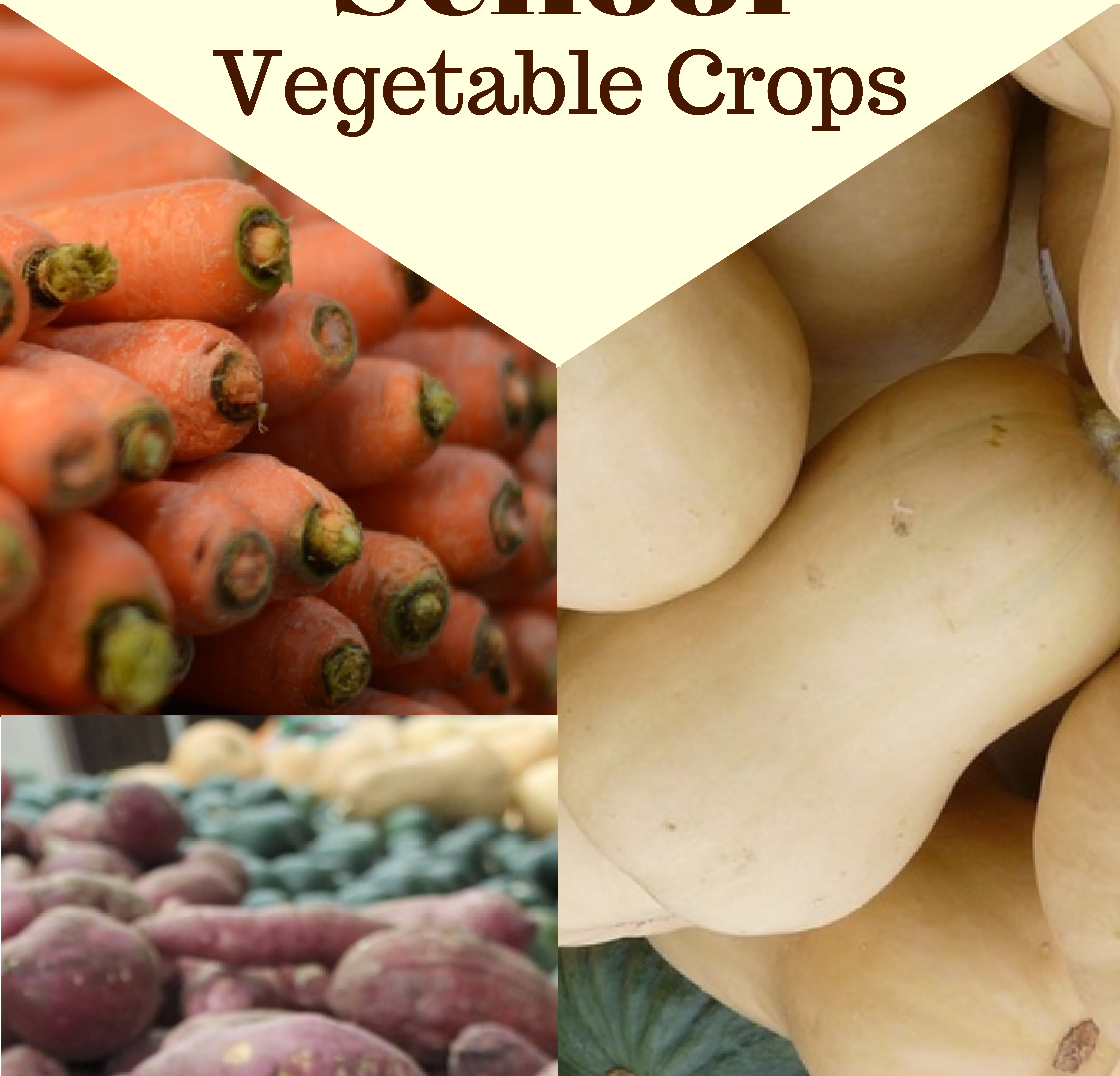
Winter Storage School

Vegetable Crops



Sponsored by:

Cornell Cooperative Extension

Eastern NY Commercial Horticulture Program

&

HUDSON VALLEY FARM HUB

Contact Information

Chris Callahan
Assistant Extension Professor of Agricultural Engineering at the University of Vermont
Email: chris.callahan@uvm.edu
Web: https://www.uvm.edu/extension/profiles/chris_callahan

Jean-Paul Courtens
Hudson Valley Farm Hub and Roxbury Farm
Email: jeanpaul@hvfarmhub.org

Crystal Stewart
Vegetable Specialist - ENYCHP
Email: cls263@cornell.edu

ENYCHP Web Address
https://enych.cce.cornell.edu/

Check us out on Facebook!

Farm Hub Web Address
http://hvfarmhub.org/

Section One:
Keys to Success with Growing Storage Crops

Table of Contents:

-Notes-

-Notes-

Source: Dr. Margaret McGrath, LIHREC, Cornell University. 2016.

Winter Squash Variety	Black Rot BR	Fusarium Wilt (Race 0, 1 or 2) FW	Gummy stem blight GSB	Powdery Mildew PM	Podi Virus PV	Zucchini Yellow Mosaic Virus ZYMV	Cold C	Cracking Cr	Heat H	Seed Company	Organic Seed OG	Untreated Seed UT	Treated Seed T	Specifics S
Ace of Spades (acorn)				X						C				H
Autumn Delight F1 (acorn)				X						HS, RS, RU, SI, ST, SW				H
Betternut 1744 F1 (butternut)				X						RU				FM
Betternut 401 F1 (butternut)				X				X		RU, SI				FM
Betternut 900 F1 (butternut)				X						HO, RU				H
Big Chief F1 (butternut)				X						HO				H
Black Bellota F1 (acorn)				X	X					C, N				H
BonBon F1 (buttercup)				X						HO, HS			X	H
Buffy F1				X	X					N				H
Bugle (butternut)				X						HO				H
Bush Delicata				X						H, HO, HS, RHS, RS, RU, SW, TR	X		X	H
Butterfly F1 (butternut)				X						HS, RS, ST		X	X	FM

Butterscotch PMR F1 (mini-butternut)				X						JO				H
Celebration F1 (acorn)				X						HO, RU, ST, SW				H
Chieftain F1 (butternut)				X						HS			X	H
Eastern Rise F1				X			X		X	F				H
Fairy F1				X						TR				H
Geisha F1				X		X				HO, N				H
Giant Argonaut Butternut										RHS				H
Golden Butta Bowl F1				X		X				N				H
Hai						X				C				H
Harlequin (acorn)				X						RU				H
Hooligan F1				X						JO				H
Honey Bear F1 (acorn)				X						JO, P, ST, TS				H
Honey Nut (butternut)				X						G, H, HS		X	X	H
JWS 6823 (butternut)				X						JO	X			H
Metro F1 (butternut)				X						JO				H
Narragansett F1 (butternut)				X		X				HO, HS, N				FM
Nutterbutter (butternut)				X						H				H
Orange Summer F1				X						H				H
Pinata PMT F1				X						N				H
Polaris F1								X		C, SW				H

Royal Ace F1 (acorn)				X						HS, RS, ST, SW		X	X	H
Speckled Hound F1						X				HS, SI			X	OP
Speckled Pup F1				X		X				HO, HS, N			X	H
Sugarbush F1 (acorn)				X						H				H
Sugar Dumpling F1 (acorn)				X						H				OP
Sunshine F1 (buttercup)				X						JO		X	X	H
Sun Spot F1 (buttercup)				X						HO				H
Sweet Lightning				X						RU				H
Sweet Mama F1 (kabocha)		X								ST				H
Sweet Reba F1 (acorn)				X						F, H, HO		X		H
Table Star (acorn)				X						RU				H
Table Treat (acorn)				X						HO, RU				H
Taybelle F1 (acorn)				X						HO, RS, RU, SI, ST, SW				H
Tiana F1 (butternut)				X		X				H				H
TipTop (acorn)				X						JO				H
Unique F1 (spaghetti)				X						HO, N				H
Waltham (butternut)										H				H
Winter Sweet F1 (kabocha)	X									JO				H

Key to the table

DR/DT = Disease Resistance/Tolerance listed in catalogue (no disease specified for resistance)

Specifics:

H = Hybrid

OP = Open Pollinated

FM = Fresh Market

HG = Home Garden

Seed Companies (2016 Catalogues checked):

AT = American Takii

B = Burpee

BI = Botanical Interest Seed

C = Clifton

F = Fedco

G = Gurney's Seed

H = High Mowing Organic Seeds

HO = Holmes

HS = Harris Seed

JO = Johnny's Seed

N = NeSeed

P = Park Seed

RHS = R.H. Shumway's

RS = Rispens Seed

RU = Rupp

S = Sakata

SI = Siegers

ST = Stokes

SW = Seedway

TS = Territorial Seed

TT = Totally Tomatoes

Managing Cucurbit Powdery Mildew Successfully in NY in 2017

Margaret Tuttle McGrath
Plant Pathology and Plant-Microbe Biology Section, SIPS, Cornell University
Long Island Horticultural Research and Extension Center (LIHREC)
3059 Sound Avenue, Riverhead, NY 11901; mtm3@cornell.edu

Effectively managing powdery mildew is essential for producing a high-quality cucurbit crop. This foliar, fungal disease is common wherever cucurbits are grown, including in the northeastern U.S. This is because the pathogen produces an abundance of asexual spores (the powdery growth) easily dispersed by wind, thus it can spread widely, and the pathogen can produce a sexual spore in fall that enables it to survive over winter. Leaves affected by powdery mildew die prematurely which results in fewer fruit and/or fruit of low quality (poor flavor, sunscald, poor storability).

Powdery mildew is managed with resistant varieties and fungicides. An integrated program with both management tools is the best approach for achieving effective control because the pathogen is adept at evolving new strains resistant to individual tools such as resistant varieties or a specific fungicide. It is more difficult for new pathogen strains to develop when an integrated program is used, and effective control is more likely. Powdery mildew management program often needs adjustments as the pathogen and management tools change.

Resistant varieties are now available in most crop groups with new varieties released most years. Resistance in cucumber is standard in modern varieties and is so strong it is easy to forget this cucurbit type is susceptible until an Heirloom type is grown. Resistance in other cucurbit crop types is not adequate used alone (without fungicide applications) to prevent impact of powdery mildew on yield. Melon varieties with resistance to pathogen races 1 and 2 have exhibited very good suppression in experiments conducted at LIHREC until recently. Squash and pumpkin exhibit a moderate to low degree of resistance. Select varieties with resistance from both parents (homozygous resistance) when possible. This term is used in a few catalogues (for example Outstanding Seeds) whereas others use terms like ‘high resistance’ and ‘intermediate resistance’ or ‘tolerance’ to generally refer to homozygous and heterozygous resistance, respectively. Degree of disease suppression obtained with a variety also depends on modifying genes present. Plant breeders are actively searching for new sources of resistance to powdery mildew.

Fungicide program. The most important component of an effective management program is an effective fungicide program. And the key to that is using mobile fungicides targeted to powdery mildew. Mobile fungicides are needed for control on the underside of leaves. Because these fungicides have targeted activity, additional fungicides must be added to the program when there is a need to manage other diseases such as downy mildew and Phytophthora blight.

Alternate among targeted, mobile fungicides and apply them with a protectant fungicide to manage resistance development and avoid control failure if resistance occurs, and also to comply with label use restrictions (most mobile fungicides are not permitted used exclusively). The powdery mildew pathogen has a long history of developing resistance to fungicides (it was the first occurrence of resistance in the USA), thus a diversified fungicide program applied to resistant varieties when possible is critical for success. Always implement a resistance management program; do not wait until there is a problem. The goal is to delay development of resistance, not manage resistant strains afterwards.

When to apply fungicides. The action threshold for starting applications is one leaf with symptoms out of 50 older leaves examined. Examine both surfaces of leaves. Starting treatment after this point will compromise control and promotes resistance development. Powdery mildew usually begins to develop around the start of fruit production. Protectant fungicides applied before detection will slow initial development. After detection, continue applying fungicides weekly. Conditions are favorable for powdery mildew throughout the growing season.

Recommended targeted fungicides. Alternate among targeted, mobile fungicides in the following five chemical groups (principally the first two), and apply with protectant fungicide to manage resistance development and avoid control failure if resistance occurs, and also to comply with label use restrictions. The first two products are the newest and thus are the most important ones to have in a fungicide program. The pathogen population has been subjected to more pressure to develop resistance to the other three fungicide groups, which are listed in order based on product efficacy in recent fungicide evaluations. The first three fungicides are the only ones in these chemical groups available in the USA. See "Mobile Fungicides for Mildews and Phytophthora Blight" for more information about these and other targeted fungicides. Federal pesticide labels can be viewed and downloaded at: http://www.cdms.net/Label-Database. New York state labels are available at: http://www.dec.ny.gov/nyspad/products?0 (enter product name under 'Names' on right side of page, then click on Search at bottom of this section).

Vivando (FRAC Code U8) is a new fungicide with a new mode of action. Cucurbits are on a supplemental label. It has exhibited excellent control in fungicide evaluations conducted recently. Activity is limited to powdery mildew. Do not mix with horticultural oils. It can be applied three times per year with no more than two consecutive applications. REI is 12 hr. PHI is 0 days.

Torino (FRAC Code U6) is a new fungicide with a new mode of action. It has exhibited excellent control in fungicide evaluations conducted recently. Activity is limited to powdery mildew. It can only be applied twice to a field in a 12-mo period. Consecutive applications are not recommended. REI is 4 hr. PHI is 0 days.

Quintec (FRAC Code 13) has been consistently effective in fungicide evaluations. However, insensitivity to a high concentration of Quintec (similar to the dose when applied in the field) was detected in several of the pathogen isolates collected from fungicide-treated research and commercial fields at the end of the 2015 growing season. Therefore Quintec is now recommended used less than the label permits, which is a crop maximum of four applications. Aerial applications are not permitted and no more than two consecutive applications. Activity is limited to powdery mildew. It is the only mobile fungicide that does not move into leaves: it redistributes to foliage where spray was not directly deposited, including the underside of leaves, through diffusion and a continual process of absorption and desorption in the cuticular waxes of foliage. REI is 12 hr. PHI is 3 days.

DMI fungicides (FRAC Code 3) include Proline, Procure, Rally, and Inspire Super. Additional products are registered for use outside NY. Resistance is quantitative. Highest label rate is recommended because the pathogen has become less sensitive to this chemistry. Efficacy has varied in fungicide evaluations. Proline is thought to have the greatest inherent activity and Inspire Super the least. Procure applied at its highest label rate provides a higher dose of active ingredient than the other Code 3 fungicides. Five applications can be made at this rate. REI is 12 hr. PHI is 0 days, 7 days for Proline and Inspire Super. Powdery mildew is the only labeled cucurbit disease for Procure and Rally. Proline is also labeled for Fusarium blight and gummy stem blight. Inspire Super, which contains another active ingredient (Code 9), is also labeled for Alternaria blight, anthracnose, gummy stem blight, Plectosporium blight, and Septoria leaf spot.

Carboxamide fungicides (FRAC Code 7) registered in NY are Luna fungicides, Endura, Pristine and Merivon. Only Endura and Pristine are permitted used on Long Island. Endura is recommended used sparingly if at all, and only on LI, because powdery mildew pathogen strains resistant to boscalid, active ingredient in Endura and Pristine, have been detected since 2009 in NY and likely are the reason its efficacy has been poor in some fungicide evaluations. Boscalid-resistant strains exhibit sufficient cross resistance with Merivon that it is also expected to be ineffective, but not with Luna fungicides. Luna Experience is the best choice in upstate NY. REI is 12 hr. PHI is 0 days. Maximum number of applications is 2 to 5 depending on rate used. Luna Experience also contains tebuconazole (Code 3), which needs to be considered when developing an alternation program. Luna Sensation is not recommended because it also contains trifloxystrobin (Code 11); resistance to this chemistry is very common.

Fungicide evaluations conducted each year on pumpkin at LIHREC include fungicides at risk for resistance tested alone (this is neither a labeled nor recommended commercial use pattern for these fungicides; it is done in efficacy evaluations to determine if resistance affects control). In 2016 Quintec and Procure were as effective as an alternation program while Pristine was substantially less effective. In 2015 Quintec, Pristine, and Vivando were as effective as an alternation program (69-78% control on lower leaf surfaces). Quintec and Vivando were the most effective of the targeted fungicides evaluated in 2014 (96 and 98% control); Pristine was moderately effective (54%); Procure was slightly but not significantly better (70%). In 2013 Quintec, Pristine, and Procure provided excellent control (93-99% control). In 2012 Pristine and Fontelis were ineffective (albeit treated pumpkins were numerically less severely affected by powdery mildew than the non-treated plots) while Quintec was very effective (96%) and Procure was moderately effective (57%). This documents year-to-year variation in the pathogen population.

No longer recommended. Resistant pathogen strains are sufficiently common to render the following fungicides ineffective: Topsin M (FRAC code 1; MBC fungicide) and QoI fungicides (Code 11), which include Quadris, Cabrio and Flint. Resistant strains continue to be detected commonly every year on Long Island where monitoring is being conducted.

Recommended protectant fungicides. Many fungicides have contact activity for powdery mildew; mancozeb is an exception. They include chlorothalonil, sulfur, copper, oils (mineral and botanical), potassium bicarbonate, and biologicals. Many of these products are approved for organic production (see list below). Sulfur is one of the most effective and least expensive products. Its activity is limited to powdery mildew, thus it is especially useful early in disease development when other diseases are not a concern, including as a preventive application. Melons are sensitive to sulfur especially when hot; there are tolerant varieties.

Organic fungicides. Products labeled for cucurbit powdery mildew, in addition to several formulations of copper and sulfur, include:

Actinovate AG. 0.0371% *Streptomyces lydicus* strain WYEC 108. For best results with applications to foliage, label indicates to use a non-ionic spreader-sticker. OMRI-listed. EPA Reg. No. 73314-1. Monsanto BioAg.

BacStop. 2.0% thyme, 2.0% clove & clove oil, 1.5% cinnamon, 1.0% peppermint & peppermint oil, and 1.0% garlic oil. Recommended used with EF400. Exempt from EPA registration. USAgriTech, Inc.

Companion. 0.03% *Bacillus subtilis* strain GB03. EPA Reg. No. 71065-3. Growth Products, Ltd.

Double Nickel 55 LC and WDG. *Bacillus amyloliquefacinens* strain D747, 98.8% and 25%, respectively. OMRI-listed. EPA Reg No. 70051-107 and 108, respectively. Certis USA, LLC.

EF400. 8.2% clove, 8.1% rosemary, and 6.7% peppermint. Exempt from EPA registration. No Ag Label. USAgriTech, Inc.

JMS Stylet-oil. 97.1% paraffinic oil. OMRI-listed. EPA Reg. No. 65564-1. JMS Flower Farms, Inc.

Kaligreen. 82% potassium bicarbonate. OMRI-listed. EPA Reg. No. 11581-2. Arysta LifeScience North America LLC.

KeyPlex 350 OR. 0.063% yeast extract hydrolysate from *Saccharomyces cerevisiae*. Combination of defensive proteins (alpha-keto acids) and secondary and micronutrients. Elicits systemic acquired resistance in plants against fungal and bacterial pathogens. Labeled for general disease control in vegetables with specific mention of bacterial leaf spot in tomato. EPA approval for organic production. EPA Reg. No. 73512-4. KeyPlex.

Mildew Cure (formerly GC-3 Organic fungicide). 30% cottonseed oil, 30% corn oil, 23% garlic extract. OMRI-listed. Exempt from EPA registration. JH Biotech, Inc.

MilStop. 85% potassium bicarbonate. OMRI-listed. EPA Reg. No. 70870-1-68539. BioWorks, Inc.

Organocide. 5% sesame oil. OMRI-listed. Exempt from EPA registration. Organic Laboratories, Inc.

OxiDate. 27% hydrogen dioxide. OMRI-listed. EPA Reg. No. 70299-2. BioSafe Systems, LLC.

Procidic. 3.5% Citric acid. NOP compliant; registered for use in organic agriculture with Washington State Dept of Ag. Exempt from EPA registration. Greenspire Global, Inc.

Promax. 3.5% Thyme oil. OMRI-listed. Exempt from EPA registration. Bio Huma Netics.

Regalia. 5% Extract of *Reynoutria sachalinensis*. OMRI-listed. EPA Reg. No. 84059-2. Marrone Bio Innovations, Inc.

Serenade ASO. 14.6% *Bacillus subtilis* strain QST 713. OMRI-listed. EPA Reg. No. 264-1152. Bayer CropScience.

Serenade Opti. 26.2% *Bacillus subtilis* strain QST 713. New formulation; see above products. OMRI-listed. EPA Reg. No. 264-1160. Bayer CropScience.

Sonata. 1.38% *Bacillus pumilus* strain QST 2808. OMRI-listed. EPA Reg. No. 69592-13. Bayer CropScience.

Sporatec AG. 18% rosemary oil, 10% clove oil, and 10% thyme oil. OMRI-listed. Exempt from EPA registration. Brandt Consolidated, Inc.

Thyme Guard. 23% thyme oil extract. Determined to be NOP compliant by Washington State Dept of Ag. Exempt from EPA registration. Agro Research International.

Trilogy. 70% clarified hydrophobic extract of neem oil. OMRI-listed. EPA Reg. No. 70051-2. Certis USA, LLC.

TriTek. 80% mineral oil. OMRI-listed. EPA Reg. No. 48813-1. Brandt Consolidated, Inc.

Before purchase for organic production, confirm product is acceptable for agricultural use with your certifier or your NYS DEC regional office.

In summary, to manage powdery mildew effectively in cucurbit crops: 1) select resistant varieties, 2) inspect crops routinely for symptoms beginning at the start of fruit development, and 3) apply targeted fungicides weekly with protectant fungicides and alternate amongst available chemistry based on FRAC Group code, starting at the action threshold of 1 affected leaf out of 50 older leaves. Add new fungicides to the program when they become available; substitute new for older product if they are in the same FRAC group.

Please Note: The specific directions on fungicide labels must be adhered to -- they supersede these recommendations, if there is a conflict. Note that some products mentioned are not yet registered for use on cucurbits in NY. Check state registration for all products and approval with certifier for organic products. Check labels for use restrictions. Any reference to commercial products, trade or brand names is for information only; no endorsement is intended.

Gummy Stem Blight

Fact Sheet Page: 732.70 Date: 7-1992
COOPERATIVE EXTENSION • NEW YORK STATE • CORNELL UNIVERSITY

Thomas A. Zitter, Department of Plant Pathology Cornell University

Gummy stem blight, caused by the fungus *Didymella bryoniae* as the sexual stage (perithecia giving rise to ascospores) and *Phoma cucurbitacearum* as the asexual stage (pycnidia producing conidia), is a common disease of all major cucurbits and is present wherever they are grown. Both stages of the pathogen can occur on infected tissue during the season, but they vary in importance as inoculum sources. The disease has been reported in New York since the early 1900s. Gummy stem blight refers to the foliar and stem-infecting phase of the disease, black rot to the fruit rot phase (see fact sheet, page 732.10, Fruit Rots of Squash and Pumpkins).

Symptoms and Signs

A wide range of foliar symptoms occurs on cucurbits, which can make diagnosis difficult. For example, on leaves of the muskmelon variety Earligold symptoms may be a water-soaked lesion on the leaf margin, interveinal necrotic scorch, and randomly distributed irregularly shaped circular lesions (fig. 1). Under certain weather conditions all symptoms may occur in a naturally infected field at the same time. Some lesions may be surrounded by a yellow halo, and when spots dry up, they often crack. On pumpkin, a non-descript marginal necrosisis followed by larger, wedge-shaped necrotic areas common to the earlier appearance of powdery mildew (fig. 2). The association of susceptibility to powdery mildew and occurrence of gummy stem blight is discussed later. Leaf symptoms on cucumber and squash are infrequent but are similar in appearance to those on pumpkin. Pycnidia, the asexual fruiting bodies, appear on affected leaves as small black specks, but if the tissue is rapidly killed, as on muskmelon, these diagnostic signs will not be evident on the foliage.

Infected stems first show water-soaked lesions and later appear tan. Older stems, particularly of muskmelon and cucumber, show pycnidiawithin the affected tissue (fig. 3). Stem lesions often cause gummy, reddish-brown or black beads to exude, a symptom that can be confused with Fusarium wilts and injury caused by insect feeding. In the latter cases, however, pycnidia are not present. Perithecial fruiting bodies, which appear similar, may also be embedded in the same lesion.

Disease Cycle

The gummy stem blight fungus is both seed- and soil-borne. The pathogen may be carried in or on infested seed. In the absence of host plants, the fungus can overwinter for a year and a half or more on infected crop residue. The exact length of survival in the Northeast is currently being studied. The fungus survives as dormant mycelium or as chlamydospores (thick-walled modifications of the mycelium). In northern areas of the country in the spring, pycnidia are produced, giving rise to conidia, which serve as the primary inoculum. Under laboratory conditions, young pycnidia appear light brown (fig. 4, left), whereas perithecia already are black (fig. 4, right). As the pycnidia age, they become black, as shown in figure 3. Conidia are released through a pore (ostiole) in the pycnidia (fig. 5), and if moisture is high, conidia exude as "spore horns" containing thousands of conidia (fig. 6). Conidia vary in size, are short and cylindrical, with usually one septum near the middle, or they may be unicellular. Under moist conditions, they are readily dispersed by splashing water.

Both temperature and moisture are critical for germination, sporulation, penetration of conidia, and subsequent symptom development, but moisture (relative humidity over 85 percent, rainfall and duration of leaf wetness from 1 to 10 hours) has the greatest influence. The optimal temperature for symptom development varies depending on the cucurbit; for watermelon 75° F is optimal, for cucumber 75-77° F, and for muskmelon 65° F. The optimal temperature for muskmelon reportedly is lower because its resistance increases at high temperatures. This can be significant to determine when early-season disease scouting should be initiated for future control. Penetration by conidia is probably direct and does not need to occur through stomates or wounds. Wounding, striped cucumber beetles, and aphid feeding, along with powdery mildew infection, predispose plants to infection. The additional nutrients provided by such injuries enhance gummy stem blight infection. Symptoms of gummy stem blight (black rot) fruit infection may be evident in the field, as shown on butternut squash in figure 7, or develop later in storage.

Cultural Control

Disease-free seed should be used for all cucurbit plantings. Obtain seed from reputable sources. If seed is to be saved from open-pollinated varieties, these should originate from disease free plantings and should be harvested at a location where there is no contamination by airborne conidia. Use of seed disinfectants does not guarantee that all seed is disease-free. Seed disinfectants are more effective when used as solutions or suspensions than as dry dust treatments. To be safe, growers should follow a minimum 2-year rotation out of all cucurbits. To encourage decay of plant debris, crop refuse should be plowed under as soon as possible after harvest. Powdery-mildew-resistant (PMR) cucumber and muskmelon varieties should be grown to reduce the opportunity for gummy stem blight infections. PMR pumpkin and summer and winter squash will be available soon. Cucumber beetles and aphids should be controlled to reduce predisposing cucurbits to disease.

Chemical Control

Although the release of additional PMR cucurbits is imminent, chemical control of powdery mildew and gummy stem blight is important to reduce foliar infections and subsequent fruit infections. Recent research has shown that control of powdery mildew either by chemicals or by genetic resistance can significantly reduce black rot in pumpkin and winter squash. We currently recommend midseason control of powdery mildew (mid-July to earlyAugust) with the exact timing of specific sprays determined by scouting. Plants that already have set fruit are more likely to show early mildew infections. Powdery mildew inoculum arrives from southern states as airborne conidia and thus cannot be controlled by crop rotation. Control of gummy stem blight (GSB) should begin soon after the appearance of powdery mildew (earlier if GSB originates from seed or local inoculum sources) although the exact timing remains to be determined, mainly because of the difficulty of accurately identifying this disease on most cucurbits. Combination sprays are recommended because of the need to control powdery mildew along with gummy stem blight and other foliar and fruit diseases (anthracnose, downy mildew, Alternaria leaf blight, and Septoria leaf and fruit spot). The combinations to be used should be determined by scouting for these diseases. Specific fungicides for control of downy mildew should be included if this rapidly spreading disease is reported in the area. Refer to the current Cornell Pest Management Recommendations for Commercial Vegetable Production or local county newsletters for an updated list of available fungicides and their proper use.


Fig. 1.


Fig. 2.


Fig. 3.


Fig. 4.

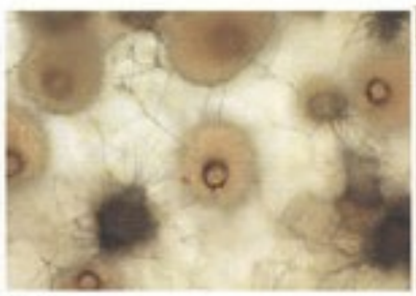


Fig. 5.

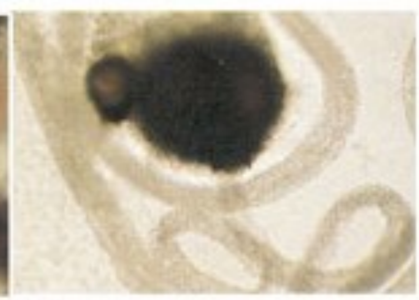


Fig. 6.


Fig. 7.

Acknowledgments- *Appreciation is extended to Louis Hsu for laboratory assistance and to Kent Loeffler for photographic assistance. Portions of the research leading to results were funded by the New York State Integrated Pest Management Program and Hatch Project NYC 153-417.*

POSTHARVEST HANDLING OF

SWEETPOTATOES

Brooke A. Edmunds | Graduate Research Assistant, Dept. of Plant Pathology, N.C. State University

Michael D. Boyette | Professor, Dept. of Biological and Agricultural Engineering, N.C. State University

Christopher A. Clark | Professor, Dept. of Plant Pathology and Crop Physiology, Louisiana State University

Donald M. Ferrin | Assistant Professor, Dept. of Plant Pathology and Crop Physiology, Louisiana State University

Tara P. Smith | Assistant Professor, Sweet Potato Research Station, Louisiana State University

Gerald J. Holmes | Associate Professor, Dept. of Plant Pathology, N.C. State University

THE AUTHORS GRATEFULLY ACKNOWLEDGE THE FOLLOWING FOR REVIEW OF THIS BULLETIN: Charles Averre, Professor Emeritus, Dept. of Plant Pathology, N.C. State University; William Branch, Professor Emeritus, Dept. of Biological and Agricultural Engineering, Louisiana State University AgCenter; Abner Hammond, Professor, Dept. of Entomology, Louisiana State University AgCenter; George Kennedy, Professor, Dept. of Entomology, N.C. State University; and Jonathan Schultheis, Professor, Dept. of Horticulture, N.C. State University.

Proper Handling Pays

The importance of proper handling of sweetpotatoes, from the farmer's field to the consumer's kitchen, cannot be overemphasized. Studies show that significant postharvest losses occur because of improper handling and other factors. On average in the United States, 20 to 25 percent is lost in sweetpotatoes during curing and storage, another 5 to 15 percent is lost during shipping and retailing, and an additional 10 to 15 percent is lost after sweetpotatoes reach the consumer. In total, poor handling practices may result in the loss of more than half the harvested sweetpotatoes before they reach the consumer's table.

Providing consumers with an acceptable product (Figure 1) demands attention to the unique postharvest requirements of sweetpotatoes. This publication has been prepared to acquaint growers, packers, and shippers with the most current information and recommendations for proper postharvest handling of sweetpotatoes. It incorporates new information on good agricultural practices (GAPs) and packing line sanitation and configurations, and the results of an in-depth packing line survey. Also included are plans and operating recommendations for a moderate-sized sweetpotato curing and storage facility with negative horizontal ventilation (NHV). Photographs of common postharvest diseases, abiotic damage not caused by disease organisms, and insects are in Appendix 1.

Figure 1. Proper postharvest handling is required to produce quality sweetpotatoes for retail markets. (PHOTO BY G.HOLMES)

Figure 2. Freshly harvested roots exude latex when cut. (PHOTO BY G. HOLMES)

Figure 3. No latex exudation when cut: a symptom of chilling injury. (PHOTO BY T. SMITH)

Figure 4. Proper cutting of slips is done above the soil line to avoid contact of the knife blade with soil. A contaminated blade may transfer disease organisms from the soil to the cut ends of slips. (PHOTO BY G. HOLMES)

Growing for Improved Postharvest Quality

Successful storage starts with high-quality roots. Events occurring during the growing season may later negatively affect postharvest quality. Some factors such as weather are impossible to control, whereas others (such as fertilization) can be manipulated by a grower to ensure that a quality product goes into storage.

The weather during the growing season, especially just before and during harvest, has a major effect on postharvest quality. An extended drought followed by heavy rain frequently accelerates growth, which often produces roots with thin, delicate skin that are prone to growth cracks (Figure 53). Besides being unappealing to the customer, these cracks provide infection sites for soilborne pathogens. Additionally, heavy rains that saturate soil for more than a few hours can cause root asphyxiation. Water-saturated soil allows carbon dioxide to accumulate in the roots, a condition that may also be accompanied by a depletion of oxygen. Asphyxiation can happen at any time, but it is more likely to occur during warm periods, especially if the vines have been removed before harvest. Sweetpotatoes that have been asphyxiated may appear healthy for several days or weeks, but if injury was severe, the roots will die and begin decomposing in storage. The first indication of a problem may include the lack of exuding latex from the vascular ring of a cut sweetpotato (Figures 2 and 3). The smell of alcohol, yeast or "decay," increased numbers of fruit flies, and secondary diseases such as bacterial or fungal infections also appear during storage of asphyxiated sweetpotatoes.

Nitrogen fertilization timing and rates affect postharvest quality. While the final studies are not in yet, good cultural practices dictate the use of nitrogen fertilizers early and sparingly. Increasing yield with additional nitrogen fertilizer may result in an abundance of large, misshaped roots. Research on calcium fertilizers has also produced variable results. Some studies show a beneficial effect on skin quality and appearance, while most show no effect on quality.

Field practices control some postharvest diseases. Fusarium root rot, Fusarium surface rot, and black rot are just three diseases that start as infections in the field but develop symptoms in storage. Growers can reduce losses from these diseases by avoiding fields with a known history of disease and by using slips (plant cuttings used as transplants) that have been cut instead of pulled, which avoids transferring disease from the plant bed into the field (Figure 4). Proper curing is also essential to controlling many diseases and is discussed in the curing section on page 11.

Harvesting for Quality

Sweetpotatoes have thin, delicate skin that is easily damaged by cuts and abrasions (Figure 5). Rough handling during harvest can contribute significantly to postharvest losses. These losses result from shrinkage (weight loss), inferior appearance of the roots, and diseases that enter through damaged skin. Plowing and hand harvesting or harvesting with a mechanical digger will give satisfactory results if done carefully. Most growers harvest into either 20-bushel or 40-bushel "double" wooden bins, although some 20-bushel plastic bins are used. (See page 44 for more details on pallet bin dimensions and capacity.) Workers should not throw or step on the roots in the bins (Figure 6). Pallet bins should never be overfilled, as this prevents proper bin stacking. Improper stacking will injure the roots, not just on top, but throughout the bin (Figure 7). Overfilling can also

Figure 5. Skinning due to abrasions incurred during postharvest handling. (PHOTO BY G. HOLMES)

Figure 6. Gentle handling during harvesting operations is critical to maintaining quality and reducing decay. (PHOTO BY G. HOLMES)

Figure 7. Bins are often slightly overfilled initially so that as roots settle, the bin's holding capacity remains maximized. However, if sufficient settling does not occur, overfilled bins will lead to tremendous injury when stacked. (PHOTO BY G. HOLMES)

Figure 8. Sunscald (A) with deer feeding injury (B); undamaged root skin under the soil line (C). (PHOTO BY G. HOLMES)

Figure 9. Surface pitting caused by chilling injury. (PHOTO BY G. HOLMES)

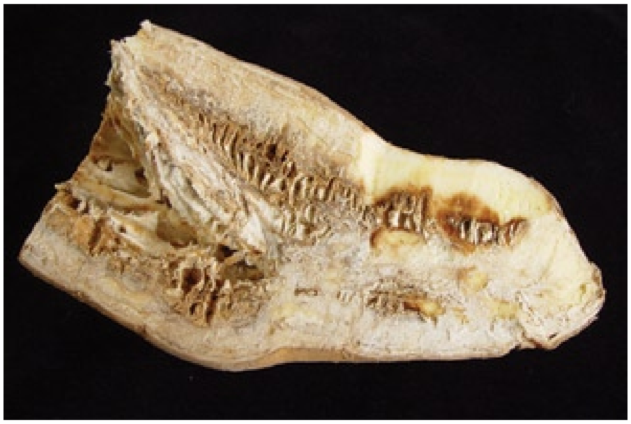


Figure 10. Internal voids caused by dry matter loss. (PHOTO BY G. HOLMES)

Figure 11. Secondary *Penicillium* mold invasion following chilling injury. (PHOTO BY G. HOLMES)

cause stability problems when stacking. Likewise, transport over rough roads or excess movement at the curing and storage facility can result in additional damage. Although prompt and proper curing can help heal injuries, an injured sweetpotato will never regain its original appearance.

After roots are dug, they should be promptly loaded and moved to the storage facility. Otherwise, there is a risk of injury by sunscald or chilling, depending on environmental conditions. Sunscald (Figure 8), a physiological condition that causes a darkening or death of the skin, may result after as few as 30 minutes of exposure to bright sunlight. If sweetpotatoes are allowed to remain in bright sun for several hours, either before they are picked up or after they are placed in the pallet bin, they are almost sure to develop sunscald. Sunscald is unattractive and can be a site for postharvest decay. Some cultivars of sweetpotatoes are more susceptible to sunscald than others, and it is more conspicuous on light or flesh-colored cultivars.

Chilling injury becomes a concern during late-season harvests. Although sweetpotatoes freeze at about 30°F (1°C) and are immediately ruined, they are injured at temperatures below 50°F (10°C). The extent of the chilling injury is a function of both the temperature and length of exposure. For example, one hour at 40°F (4°C) may produce the same level of injury as five hours at 45°F (7°C). Chilling injury is also cumulative; one short episode below 50°F (10°C) may not produce any noticeable injury, whereas many short episodes may cause significant injury. Unharvested sweetpotatoes may not be harmed by a frost, depending on the temperature of the soil surrounding the roots. Harvest as soon as possible after frost has killed the vines to ensure that no injury occurs. Never leave harvested sweetpotatoes in the field overnight, as cooling may cause substantial injury. Damage caused by chilling may not appear for many weeks—or even several months—after the chilling occurs.

Chilling injury is expressed in many ways and can be difficult to diagnose. The most common symptoms are surface pitting, greatly accelerated respiratory activity (dry matter loss), and an increase in susceptibility to decay (especially blue mold caused by *Penicillium* spp. See Figures 9 through 11). Other common symptoms include internal breakdown and voids, hardcore, failure to sprout, reduced culinary character (color, texture, taste, and aroma), and discoloration (darkening) of flesh when exposed to air. If chilling was severe, the roots may not exude latex when cut (Figures 2 and 3), or die and begin to decompose in storage.

Vermont Vegetable and Berry News – September 15, 2014
compiled by Vern Grubinger, University of Vermont Extension
(802) 257-7967 ext. 303, vernon.grubinger@uvm.edu
www.uvm.edu/vtvegandberry

HARVEST TIPS FOR WINTER SQUASH AND PUMPKINS

Harvest fruits when they are mature and the rind is hard, but before night temperatures are below 40F, and well before a frost. Remember that chilling injury is cumulative, so with each exposure below 50F there is some loss of storage life.

Do not harvest or handle wet fruit if possible. Do not let harvested fruit get wet.

Harvest fruit by cutting the stem with pruning shears to leave a about a 1-inch stump on the squash (3 inch for pumpkins.)

Harvest, pack, handle, and store fruit carefully to avoid injuries. Never dump/drop squash.

Separate all fruit that are immature, injured, or have rot or blemishes. These fruit should not be stored.

Do not pick up freshly harvested fruit by the stem as it may separate from the fruit and provide easy access for rot organisms.

Do not stack the fruit higher than 3 ft. to avoid compression injury.

Do not permit harvested or stored fruit to get wet - avoid passing warm air over cold fruit as condensation will occur.

Washing is usually not desirable, but if washing is necessary (muddy fruit) be sure the water is chlorinated (at least 50 ppm, approximately one part 5.25% liquid bleach to 999 parts water). Organic treatment is StorOx or Sanidate 5.0 at labeled rate (60 oz per 100 gal for the latter.) Though I cannot find any data that post-harvest treatment prevents disease. Dry thoroughly before storing.

To harden rind you can cure for 10 to 20 days at 80 to 85F with good ventilation (e.g. four air exchanges per day). UMass suggests a warm dry greenhouse (70-80°F) with good air circulation, such as a greenhouse, for up to two weeks. There is mixed info on the benefit of curing winter squash but from what I've read by hardening the skin it will reduce weight loss in storage and this may also prevent subsequent handling injuries, which can lead to disease. If you are removing stems at harvest then I think curing is important to heal any would that is created.

Harvested fruit should be stored with good ventilation (at least one air exchange per day) at 50 to 55F and 50 to 75% relative humidity. UCDavis says 55-59F with 60% RH optimal. Higher humidity promotes rots. Stack bins to allow air to move in between.

Check stored fruits often for signs of decay and remove affected fruit.

References:
https://extension.umass.edu/vegetable/articles/pumpkin-and-winter-squash-harvest-and-storage
http://www.ces.ncsu.edu/hil/hil-24-c.html
http://www.ba.ars.usda.gov/hb66/pumpkin.pdf

For lots of good info on crops storage see Chris Callahan's Ag Engineering blog:
http://blog.uvm.edu/cwcallah/crop-storage-resources/

TIPS FOR BEST ONION BULB QUALITY

Vermont Vegetable and Berry News – September 15, 2014

Adapted from Christy Hoepting, Cornell Vegetable Program

Do not pull onions and leave them in the hot sun when temperatures are high because they can get sunscald, especially if the relative humidity is high and they are pulled on the green side. A common technique for field drying is to orient the pulled onions so that the leaves lay over top of the bulbs. Some growers move the pulled onions with the tops on into a greenhouse or high tunnel to dry. Temperatures should be held below 85 °F, which will probably require leaving everything wide open. Black shade curtain/cloth over the house can also help to moderate temperature. Ensure good air movement.

Harvest dry onions during the cooler part of the day if it is hot out, and as long as they are not wet from dew or rain. Storage-bound onions should only be topped when the neck is dry and has no green tissue (i.e. the tissue does not slide when you roll the neck between your fingers). Bacterial diseases and black mold can enter into and move through green tissue into the bulbs. These diseases do not infect or move in dry tissue. Leave 2-3 inches of neck on the bulb when topping. This increases the distance from the cut surface to the bulb for fungal and bacterial pathogens to travel. Theoretically, if the neck dries down before the disease gets to the bulb, the bulb should be sound in storage.

If onions are dying standing up due to excessive leaf dieback caused by disease or other stress, and they are not lodging, they should be pulled and note that it may take a bit longer for the necks to dry on these onions. Conduct harvest practices when the weather is dry. Ideally, onions should not be handled when wet. When wet harvested onions are placed into boxes, it takes longer for them to cure properly, and the added moisture can stimulate disease development and rooting, which in turn will stimulate sprouting. Avoid bruising during harvest procedures. Reduce drops to 6" and pad sharp surfaces.

For optimum storage quality onions must be cured soon after harvest. Curing decreases the incidence of neck rot and bacterial diseases, reduces water loss during storage and is desirable for development of good scale color. Optimum conditions are 68-86°F and 70% relative humidity for at least 12 to 24 h. Best skin color develops at 75-90°F. Artificial curing can be done with outside air, which is heated to approximately 77°F or 3-5 °F above the ambient air temperature. Avoid temperatures greater than 82°F, because bacterial diseases and black mold are more likely to develop. A lower temperature, down to 68°F should be used if onions are poorly skinned, have been touched by frost or have bacterial diseases. Relative humidity should not fall below 65% or exceed 80%. RH going into the boxes should ideally be 50% and less than 100% coming out.

Airflow should be no less than 3 cubic feet per minute per cubic foot of product. The optimum temperature for long term storage of onions is 32°F with 65-70% relative humidity, but it is important to bring them down to this temperature slowly. Avoid condensation by not circulating air onto onions that is a warmer temperature than the onions.

Section Two:
Post– Harvest Handling

Table of Contents:

-Notes-

-Notes-

PROPERTIES AND RECOMMENDED CONDITIONS FOR LONG-TERM STORAGE OF FRESH FRUITS AND VEGETABLES

Listed alphabetically according to common name

Compiled by Marita Cantwell (email: micantwell@ucdavis.edu)

Common name	Scientific name	Storage temperature °C	°F	Relative humidity %	Highest freezing temperature °C	°F	Ethylene* production	Ethylene** sensitivity	Approximate storage-life	Observations and beneficial CA conditions
Acerola; Barbados cherry	*Malpighia glabra*	0	32	85-90	-1.4	29.4			6-8 weeks	
African horned melon; Kiwano	*Cucumis metuliferus*	13-15	55-59	90			L	M	3-6 months	
Amaranth; Pigweed	*Amaranthus spp.*	0-2	32-36	95-100			VL	M	10-14 days	
Anise; Fennel	*Foeniculum vulgare*	0-2	32-36	90-95	-1.1	30.0			2-3 weeks	
Apple	*Malus pumila*									2-3% O2 + 1-2% CO2
not chilling sensitive		-1.1-0	30-32	90-95	-1.5	29.3	VH	H	3-6 months	
chilling sensitive	Yellow Newtown, Grimes Golden, McIntosh,	4	40	90-95	-1.5	29.3	VH	H	1-2 months	
Apricot	*Prunus armeniaca*	-0.5-0	31-32	90-95	-1.1	30.0	M	M	1-3 weeks	2-3% O2 + 2-3% CO2
Artichoke										
Globe artichoke	*Cynara acolymus*	0	32	95-100	-1.2	29.9	VL	L	2-3 weeks	2-3% O2 + 3-5% CO2
Chinese artichoke	*Stachys affinia*	0	32	90-95			VL	VL	1-2 weeks	
Jerusalem artichoke	*Helianthus tuberosus*	-0.5-0	31-32	90-95	-2.5	27.5	VL	L	4 months	
Arugula	*Eruca vesicaria var. sativa*	0	32	95-100			VL	H	7-10 days	
Asian pear, Nashi	*Pyrus serotina; P. pyrifolia*	1	34	90-95	-1.6	29.1	H	H	4-6 months	
Asparagus, green, white	*Asparagus officinalis*	2.5	36	95-100	-0.6	31.0	VL	M	2-3 weeks	5-12% CO2 in air
Atemoya	*Annona squamosa x A. cherimola*	13	55	85-90			H	H	2-4 weeks	3-5% O2 + 5-10% CO2
Avocado	*Persea americana*									
cv Fuerte, Hass		3-7	37-45	85-90	-1.6	29.1	H	H	2-4 weeks	2-5%O2 + 3-10% CO2
cv. Fuchs, Pollock		13	55	85-90	-0.9	30.4	H	H	2 weeks	
cv. Lula, Booth		4	40	90-95	-0.9	30.4	H	H	4-8 weeks	
Babaco, Mt. papaya	*Carica candamarcensis*	7	45	85-90					1-3 weeks	
Banana	*Musa paradisiaca var. sapientum*	13-15	55-59	90-95	-0.8	30.6	M	H	1-4 weeks	2-5% O2 + 2-5% CO2
Barbados cherry	see Acerola									
Beans										
Snap; Wax; Green	*Phaseolus vulgaris*	4-7	40-45	95	-0.7	30.7	L	M	7-10 days	2-3% O2 + 4-7% CO2
Fava, Broad beans	*Vicia faba*	0	32	90-95					1-2 weeks	
Lima beans	*Phaseolus lunatus*	5-6	41-43	95	-0.6	31.0	L	M	5-7 days	
Winged bean	*Psophocarpus tetragonolobus*	10	50	90					4 weeks	
Long bean; Yard-long	*Vigna sesquipedalis*	4-7	40-45	90-95			L	M	7-10 days	

Common name	Scientific name	Storage temperature °C	°F	Relative humidity %	Highest freezing temperature °C	°F	Ethylene* production	Ethylene** sensitivity	Approximate storage-life	Observations and beneficial CA conditions
Beet, bunched	*Beta vulgaris*	0	32	98-100	-0.4	31.3	VL	L	10-14 days	
beet, topped		0	32	98-100	-0.9	30.3	VL	L	4 months	
Berries										
Blackberries	*Rubus spp.*	-0.5-0	31-32	90-95	-0.8	30.6	L	L	3-6 days	5-10% O2 + 15-20% CO2
Blueberries	*Vaccinium corymbosum*	-0.5-0	31-32	90-95	-1.3	29.7	L	L	10-18 days	2-5% O2 + 12-20% CO2
Cranberry	*Vaccinium macrocarpon*	2-5	35-41	90-95	-0.9	30.4	L	L	8-16 weeks	1-2% O2 + 0-5% CO2
Dewberry	*Rubus spp.*	-0.5-0	31-32	90-95	-1.3	29.7	L	L	2-3 days	
Elderberry	*Rubus spp.*	-0.5-0	31-32	90-95	-1.1	30.0	L	L	5-14 days	
Loganberry	*Rubus spp.*	-0.5-0	31-32	90-95	-1.7	28.9	L	L	2-3 days	
Raspberries	*Rubus idaeus*	-0.5-0	31-32	90-95	-0.9	30.4	L	L	3-6 days	5-10% O2 + 15-20% CO2
Strawberry	*Fragaria spp.*	0	32	90-95	-0.8	30.6	L	L	7-10 days	5-10% O2 + 15-20% CO2
Bittermelon; Bitter gourd	*Momordica charantia*	10-12	50-54	85-90			L	M	2-3 weeks	2-3%O2 + 5% CO2
Black salsify; Scorzonera	*Scorzonera hispanica*	0-1	32-34	95-98			VL	L	6 months	
Bok choy	*Brassica chinensis*	0	32	95-100			VL	H	3 weeks	
Breadfruit	*Artocarpus altilis*	13-15	55-59	85-90					2-4 weeks	
Broccoli	*B. oleracea* var. *Italica*	0	32	95-100	-0.6	31.0	VL	H	10-14 days	1-2% O2 + 5-10% CO2
Brussels sprouts	*Brassica oleracea var. Gemnifera*	0	32	95-100	-0.8	30.5	VL	H	3-5 weeks	1-2% O2 + 5-7% CO2
Cabbage										
Chinese; Napa	*Brassica campestris* var. *Pekinensis*	0	32	95-100	-0.9	30.4	VL	M-H	2-3 months	1-2% O2 + 0-5% CO2
Common, early crop	*B. oleracea* var.*Capitata*	0	32	98-100	-0.9	30.4	VL	H	3-6 weeks	
late crop	"	0	32	95-100	-0.9	30.4	VL	H	5-6 months	3-5% O2 + 3-7% CO2
Cactus pads or stems, Nopalitos	*Opuntia spp.*	5-10	41-50	90-95			VL	M	2-3 weeks	
Cactus fruit; Prickly pear fruit	*Opuntia spp.*	5	41	85-90	-1.8	28.7	VL	M	2-6 weeks	2%O2 +2-5%CO2
Caimito	see Sapotes									
Calamondin	see Citrus									
Canistel	see Sapotes									
Carambola, Starfruit	*Averrhoa carambola*	9-10	48-50	85-90	-1.2	29.8			3-4 weeks	
Carrots, topped	*Daucus carota*	0	32	98-100	-1.4	29.5	VL	H	3-6 months	no CA benefit; ethylene causes bitterness
bunched; immature	"	0	32	98-100	-1.4	29.5	VL	H	10-14 days	ethylene causes bitterness
Cashew apple	*Anacardium occidentale*	0-2	32-36	85-90					5 weeks	
Cassava, Yucca, Manioc	*Manihot esculenta*	0-5	32-41	85-90			VL	L	1-2 months	no CA benefit
Cauliflower	*Brassica oleracea* var. *Botrytis*	0	32	95-98	-0.8	30.6	VL	H	3-4 weeks	2-5% O2 + 2-5% CO2

Common name	Scientific name	Storage temperature °C	°F	Relative humidity %	Highest freezing temperature °C	°F	Ethylene* production	Ethylene** sensitivity	Approximate storage-life	Observations and beneficial CA conditions
Celeriac	*Apium graveolens var. Rapaceum*	0	32	98-100	-0.9	30.4	VL	L	6-8 months	2-4%O2 + 2-3%CO2
Celery	*Apium graveolens* var. *Dulce*	0	32	98-100	-0.5	31.1	VL	M	1-2 months	1-4%O2 + 3-5%CO2
Chard	*Beta vulgaris* var. *Cicla*	0	32	95-100			VL	H	10-14 days	
Chayote	*Sechium edule*	7	45	85-90					4-6 weeks	
Cherimoya; Custard apple	*Annona cherimola*	13	55	90-95	-2.2	28.0	H	H	2-4 weeks	3-5% O2 + 5-10% CO2
Cherries, sour	*Prunus cerasus*	0	32	90-95	-1.7	29.0	VL	L	3-7 days	3-10% O2 + 10-12% CO2
Cherries, sweet	*Prunus avium*	-1 to 0	30-32	90-95	-2.1	28.2	VL	L	2-3 weeks	10-20% O2 + 20-25% CO2
Chicory	see Endive									
Chiles	see Pepper									
Chinese broccoli; Gailan	*Brassica alboglabra*	0	32	95-100			VL	H	10-14 days	
Chinese date	See Jujube									
Chives	*Allium schoenoprasum*	0	32	95-100			VL	H	2-3 weeks	5-10%O2 + 5-10% CO2
Cilantro, Chinese parsley	See Herbs									
Citrus										
Calamondin orange	*Citrus reticulta x Fortunella spp.*	9-10	48-50	90	-2.0	28.3			2 weeks	
Grapefruit	*Citrus paradisi*									3-10% O2 + 5-10% CO2
CA, AZ, dry areas		14-15	58-59	85-90	-1.1	30.0	VL	M	6-8 weeks	
FL, humid areas		10-15	50-59	85-90	-1.1	30.0	VL	M	6-8 weeks	
Kumquat	*Fortunella japonica*	4	40	90-95			VL	M	2-4 weeks	
Lemon	*Citrus limon*	10-13	50-55	85-90	-1.4	29.4			1-6 months	5-10%O2 + 0-10%CO2
Lime, Mexican, Tahiti or Persian	*Citrus aurantifolia; C. latifolia*	9-10	48-50	85-90	-1.6	29.1			6-8 weeks	5-10%O2 + 0-10%CO2
Orange	*Citrus sinensis*									5-10% O2 + 0-5% CO2
CA, AZ, dry areas		3-9	38-48	85-90	-0.8	30.6	VL	M	3-8 weeks	
FL; humid regions		0-2	32-36	85-90	-0.8	30.6	VL	M	8-12 weeks	
Blood orange		4-7	40-44	90-95	-0.8	30.6			3-8 weeks	
Seville; Sour	*Citrus aurantium*	10	50	85-90	-0.8	30.6	L	M	12 weeks	
Pummelo	*Citrus grandis*	7-9	45-48	85-90	-1.6	29.1			12 weeks	
Tangelo, Minneola	*C. reticulata x paradisi*	7-10	45-50	85-95	-0.9	30.3			2-4 weeks	
Tangerine, Mandarin	*Citrus reticulata*	4-7	40-45	90-95	-1.1	30.1	VL	M	2-4 weeks	
Coconut	*Cocos nucifera*	0-2	32-36	80-85	-0.9	30.4			1-2 months	
Collards	*B. oleracea* var. *Acephala*	0	32	95-100	-0.5	31.1	VL	H	10-14 days	
Corn, sweet and baby	*Zea mays*	0	32	95-98	-0.6	30.9	VL	L	5-8 days	2-4%O2 + 5-10%CO2; to 4 wks, 5-10%O2+15%CO2
Cowpeas	See Peas									
Cucumber, slicing	*Cucumis sativus*	10-12	50-54	85-90	-0.5	31.1	L	H	10-14 days	3-5% O2 + 0-5% CO2
pickling		4	40	95-100			L	H	7 days	3-5% O2 + 3-5% CO2

Common name	Scientific name	Storage temperature °C	°F	Relative humidity %	Highest freezing temperature °C	°F	Ethylene* production	Ethylene** sensitivity	Approximate storage-life	Observations and beneficial CA conditions
Currants	*Ribes sativum; R. nigrum;R. rubrum*	-0.5-0	31-32	90-95	-1.0	30.2	L	L	1-4 weeks	CA can extend storage life to 3-6 months
Custard apple	see Cherimoya									
Daikon; Oriental radish	*Raphanus sativus*	0-1	32-34	95-100			VL	L	4 months	
Dasheen	see Taro									
Date	*Phoenix dactylifera*	-18-0	0-32	75	-15.7	3.7	VL	L	6-12 months	
Dill	see Herbs									
Durian	*Durio zibethinus*	4-6	39-42	85-90					6-8 weeks	3-5% O2 + 5-15% CO2
Eggplant	*Solanum melongena*	10-12	50-54	90-95	-0.8	30.6	L	M	1-2 weeks	3-5% O2 + 0% CO2
Endive, Escarole	*Cichorium endivia*	0	32	95-100	-0.1	31.7	VL	M	2-4 weeks	
Belgian endive; Witloof chicory	*Cichorium intybus*	2-3	36-38	95-98			VL	M	2-4 weeks	light causes greening; 3-4%O2 + 4-5%CO2
Epazote	See Herbs									
Fava bean	See Beans									
Feijoa, Pineapple guava	*Feijoa sellowiana*	5-10	41-50	90			M	L	2-3 weeks	
Fennel, see anise										
Fig	*Ficus carica*	-0.5-0	31-32	85-90	-2.4	27.6	M	L	7-10 days	5-10%O2 + 15-20%CO2
Garlic bulb	*Allium sativum*	-1-0	30-32	65-70	-2.0	28.4	VL	L	6-7 months	0.5%O2 + 5-10%CO2
Ginger	*Zingiber officinale*	13	55	65			VL	L	6 months	no CA benefit
Gooseberry	*Ribes grossularia*	-0.5-0	31-32	90-95	-1.1	30.0	L	L	3-4 weeks	
Granadilla	see Passionfruit									
Grape	*Vitis vinifera a=fruit; b=stem*	-0.5 - 0	31-32	90-95	-2.7 a -2.0 b	27.1 a 28.4 b	VL	L	1-6 months	2-5%O2 + 1-3%CO2; to 4 wks, 5-10%O2+10-15%CO2
American grape	*Vitis labrusca*	-1 to -0.5	30-31	90-95	-1.4	29.4	VL	L	2-8 weeks	
Grapefruit	see Citrus									
Guava	*Psidium guajava*	5-10	41-50	90			L	M	2-3 weeks	
Herbs, fresh culinary	*See specific herb*									5-10%O2 + 5-10%CO2
Basil	*Ocimum basilicum*	10	50	90			VL	H	7 days	2%O2 + 0 to<10%CO2
Chives	*Allium schoenoprasum*	0	32	95-100	-0.9	30.4	L	M		
Cilantro, Chinese parsley	*Coriandrum sativum*	0-1	32-34	95-100			VL	H	2 weeks	3%O2 +7-10%CO2; air + 7-10%CO2
Dill	*Anethum graveolens*	0	32	95-100	-0.7	30.7	VL	H	1-2 weeks	5-10%O2 + 5-10% CO2
Epazote	*Chenopodium ambrosioides*	0-5	32-41	90-95			VL	M	1-2 weeks	
Mint	*Mentha spp.*	0	32	95-100			VL	H	2-3 weeks	5-10%O2 + 5-10% CO2
Oregano	*Origanum vulgare*	0-5	32-41	90-95			VL	M	1-2 weeks	
Parsley	*Petroselinum crispum*	0	32	95-100	-1.1	30.0	VL	H	1-2 months	5-10%O2 + 5-10% CO2
Perilla, Shiso	*Perilla frutescens*	10	50	95			VL	M	7 days	
Sage	*Salvia officinalis*	0	32	90-95					2-3 weeks	
Thyme	*Thymus vulgaris*	0	32	90-95					2-3 weeks	
Horseradish	*Armoracia rusticana*	-1 to 0	30-32	98-100	-1.8	28.7	VL	L	10-12 mo.	

Common name	Scientific name	Storage temperature °C	°F	Relative humidity %	Highest freezing temperature °C	°F	Ethylene* production	Ethylene** sensitivity	Approximate storage-life	Observations and beneficial CA conditions
Husk tomato	see Tomatillo									
Jaboticaba	*Myrciaria cauliflora= Eugenia cauliflora*	13-15	55-59	90-95					2-3 days	
Jackfruit	*Artocarpus heterophyllus*	13	55	85-90			M	M	2-4 weeks	
Jerusalem artichoke	see Artichoke									
Jicama, Yambean	*Pachyrrhizus erosus*	13-18	55-65	85-90			VL	L	1-2 months	
Jujube; Chinese date	*Ziziphus jujuba*	2.5-10	36-50	85-90	-1.6	29.2	L	M	1 month	
Kaki	see Persimmon									
Kale	*Brassica oleracea var. acephala*	0	32	95-100	-0.5	31.1	VL	H	10-14 days	
Kiwano	see African horned melon									
Kiwifruit; Chinese gooseberry	*Actinidia chinensis*	0	32	90-95	-0.9	30.4	L	H	3-5 months	1-2% O2 + 3-5% CO2
Kohlrabi	*Brassica oleracea* var. *Gongylodes*	0	32	98-100	-1.0	30.2	VL	L	2-3 months	no CA benefit
Kumquat	See Citrus									
Langsat; Lanzone	*Aglaia sp.; Lansium sp.*	11-14	52-58	85-90					2 weeks	
Leafy Greens										
Cool season	*various genera*	0	32	95-100	-0.6	31.0	VL	H	10-14 days	
Warm season	*various genera*	7-10	45-50	95-100	-0.6	31.0	VL	H	5-7 days	
Leek	*Allium porrum*	0	32	95-100	-0.7	30.7	VL	M	2 months	1-2% O2 +2-5% CO2
Lemon	see *Citrus*									
Lettuce	*Lactuca sativa*	0	32	98-100	-0.2	31.7	VL	H	2-3 weeks	2-5% O2 + 0% CO2
Lima bean	see Beans									
Lime	see Citrus									
LoBok	see Daikon									
Longan	*Dimocarpus longan =Euphoria longan*	4-7	39-45	90-95	-2.4	27.7			2-4 weeks	
Long bean	See Beans									
Loquat	*Eriobotrya japonica*	0	32	90-95	-1.9	28.6			3 weeks	
Luffa; Chinese okra	*Luffa spp.*	10-12	50-54	90-95			L	M	1-2 weeks	
Lychee, Litchi	*Litchi chinensis*	1-2	34-36	90-95			M	M	3-5 weeks	3-5% O2 + 3-5% CO2
Malanga, Tania, New cocoyam	*Xanthosoma sagittifolium*	7	45	70-80			VL	L	3 months	
Mamey	see Sapote									
Mandarin	see Citrus									
Mango	*Mangifera indica*	13	55	85-90	-1.4	29.5	M	M	2-3 weeks	3-5%O2 + 5-10%CO2
Mangosteen	*Garcinia mangostana*	13	55	85-90			M	H	2-4 weeks	
Melons										
Cantaloupes and other netted melons	*Cucurbita melo* var. *reticulatus*	2-5	36-41	95	-1.2	29.9	H	M	2-3 weeks	3-5% O2 + 10-15% CO2

Common name	Scientific name	Storage temperature °C	Storage temperature °F	Relative humidity %	Highest freezing temperature °C	Highest freezing temperature °F	Ethylene* production	Ethylene** sensitivity	Approximate storage-life	Observations and beneficial CA conditions
Casaba	*Cucurbita melo*	7-10	45-50	85-90	-1.0	30.3	L	L	3-4 weeks	3-5% O_2 + 5-10% CO_2
Crenshaw	*Cucurbita melo*	7-10	45-50	85-90	-1.1	30.1	M	H	2-3 weeks	3-5% O_2 + 5-10% CO_2
Honeydew, and Orange-flesh	*Cucurbita melo*	5-10	41-50	85-90	-1.1	30.1	M	H	3-4 weeks	3-5% O_2 + 5-10% CO_2
Persian	*Cucurbita melo*	7-10	45-50	85-90	-0.8	30.6	M	H	2-3 weeks	3-5% O_2 + 5-10% CO_2
Mint	see Herbs									
Mombin	see Spondias									
Mushrooms	*Agaricus, other genera*	0	32	90	-0.9	30.4	VL	M	7-14 days	3-21%O_2 + 5-15%CO_2
Mustard greens	*Brassica juncea*	0	32	90-95			VL	H	7-14 days	
Nashi	see Asian pear									
Nectarine	*Prunus persica*	-0.5-0	31-32	90-95	-0.9	30.3	M	M	2-4 weeks	1-2% O_2 + 3-5% CO_2; internal breakdown 3-10°C
Okra	*Abelmoschus esculentus*	7-10	45-50	90-95	-1.8	28.7	L	M	7-10 days	air + 4-10%CO_2
Olives, fresh	*Olea europea*	5-10	41-50	85-90	-1.4	29.4	L	M	4-6 weeks	2-3% O_2 + 0-1% CO_2
Onions	*Allium cepa*									
Mature bulbs, dry		0	32	65-70	-0.8	30.6	VL	L	1-8 months	1-3% O_2 + 5-10% CO_2
Green onions		0	32	95-100	-0.9	30.4	L	H	3 weeks	2-4% O_2 + 10-20% CO_2
Orange	see Citrus									
Papaya	*Carica papaya*	7-13	45-55	85-90	-0.9	30.4	M	M	1-3 weeks	2-5% O_2 + 5-8% CO_2
Parsley	see Herbs									
Parsnips	*Pastinaca sativa*	0	32	95-100	-0.9	30.4	VL	H	4-6 months	ethylene causes bitterness
Passionfruit	*Passiflora spp.*	10	50	85-90			VH	M	3-4 weeks	
Peach	*Prunus persica*	-0.5-0	31-32	90-95	-0.9	30.3	M	M	2-4 weeks	1-2%O_2 + 3-5%CO_2; internal breakdown 3-10°C
Pear, European	*Pyrus communis*	-1.5 to - 0.5	29-31	90-95	-1.7	29.0	H	H	2-7 months	Cultivar variations; 1-3%O_2 + 0-5% CO_2
Pear, Asian	See Asian Pear									
Peas in pods; Snow, Snap & Sugar peas	*Pisum sativum*	0	32	90-98	-0.6	30.9	VL	M	1-2 weeks	2-3% O_2 + 2-3% CO_2
Southern peas; Cowpeas	*Vigna sinensis =V. unguiculata*	4-5	40-41	95					6-8 days	
Pepino; Melon pear	*Solanum muricatum*	5-10	41-50	95			L	M	4 weeks	
Peppers										
Bell Pepper, Paprika	*Capsicum annuum*	7-10	45-50	95-98	-0.7	30.7	L	L	2-3 weeks	2-5% O_2 + 2-5% CO_2
Hot peppers, Chiles	*Capsicum annuum and C. frutescens*	5-10	41-50	85-95	-0.7	30.7	L	M	2-3 weeks	3-5% O_2 + 5-10% CO_2
Persimmon; Kaki	*Diospyros kaki*									3-5% O_2 + 5-8% CO_2
Fuyu		0	32	90-95	-2.2	28.0	L	H	1-3 months	
Hachiya		0	32	90-95	-2.2	28.0	L	H	2-3 months	
Pineapple	*Ananas comosus*	7-13	45-55	85-90	-1.1	30.0	L	L	2-4 weeks	2-5% O_2 + 5-10% CO_2
Plantain	*Musa paradisiaca var. paradisiaca*	13-15	55-59	90-95	-0.8	30.6	L	H	1-5 weeks	

Common name	Scientific name	Storage temperature °C	Storage temperature °F	Relative humidity %	Highest freezing temperature °C	Highest freezing temperature °F	Ethylene* production	Ethylene** sensitivity	Approximate storage-life	Observations and beneficial CA conditions
Plums and Prunes	*Prunus domestica*	-0.5 - 0	31-32	90-95	-0.8	30.5	M	M	2-5 weeks	1-2%O2 + 0-5%CO2
Pomegranate	*Punica granatum*	5-7.2	41-45	90-95	-3.0	26.6	VL	L	2-3 months	3-5% O2 + 5-10% CO2
Potato, early crop	*Solanum tuberosum*	10-15	50-59	90-95	-0.8	30.5	VL	M	10-14 days	no CA benefit
late crop		4-8	40-46	95-98	-0.8	30.5	VL	M	5-10 months	no CA benefit
Pumpkin	*Cucurbita maxima*	12-15	54-59	50-70	-0.8	30.5	L	M	2-3 months	
Quince	*Cydonia oblonga*	-0.5-0	31-32	90	-2.0	28.4	L	H	2-3 months	
Radicchio	*Cichorium intybus*	0-1	32-34	95-100					4-8 weeks	
Radish	*Raphanus sativus*	0	32	95-100	-0.7	30.7	VL	L	1-2 months	1-2%O2 + 2-3%CO2
Rambutan	*Nephelium lappaceum*	12	54	90-95			H	H	1-3 weeks	3-5% O2 + 7-12% CO2
Rhubarb	*Rheum rhaponticum*	0	32	95-100	-0.9	30.3	VL	L	2-4 weeks	
Rutabaga	*Brassica napus* var. *Napobrassica*	0	32	98-100	-1.1	30.1	VL	L	4-6 months	
Sage	see Herbs									
Salsify; Vegetable oyster	*Trapopogon porrifolius*	0	32	95-98	-1.1	30.1	VL	L	2-4 months	
Sapotes										
Caimito, Star apple	*Chrysophyllum cainito*	3	38	90	-1.2	29.9			3 weeks	
Canistel, Eggfruit	*Pouteria campechiana*	13-15	55-59	85-90	-1.8	28.7			3 weeks	
Black sapote	*Diospyros ebenaster*	13-15	55-59	85-90	-2.3	27.8			2-3 weeks	
White sapote	*Casimiroa edulis*	20	68	85-90	-2.0	28.4			2-3 weeks	
Mamey sapote	*Calocarpum mammosum*	13-15	55-59	90-95			H	H	2-3 weeks	
Sapodilla, Chicosapote	*Achras sapota*	15-20	59-68	85-90			H	H	2 weeks	
Scorzonera	see Black Salsify									
Shallots	*Allium cepa var ascalonicum*	0-2.5	32-36	65-70	-0.7	30.7	L	L		
Snap bean	see Beans									
Soursop	*Annona muricata*	13	55	85-90					1-2 weeks	3-5%O2 + 5-10% CO2
Spinach	*Spinacia oleracea*	0	32	95-100	-0.3	31.5	VL	H	10-14 days	5-10%O2 + 5-10%CO2
Spondias, Mombin, Wi apple,Jobo, Hogplum	*Spondias spp.*	13	55	85-90					1-2 weeks	
Sprouts from seeds	*various genera*	0	32	95-100					5-9 days	
Alfalfa sprouts	*Medicago sativa*	0	32	95-100					7 days	
Bean sprouts	*Phaseolus sp.*	0	32	95-100					7-9 days	
Radish sprouts	*Raphanus sp.*	0	32	95-100					5-7 days	
Squash										
Summer (soft rind); Courgette	*Cucurbita pepo*	7-10	45-50	95	-0.5	31.1	L	M	1-2 weeks	3-5% O2 + 5-10% CO2
Winter (hard rind); Calabash	*Cucurbita moschata; C. maxima*	12-15	54-59	50-70	-0.8	30.5	L	M	2-3 months	large differences among varieties
Star-apple	see Sapotes									
Starfruit	see Carambola									
Strawberry	see Berries									

Common name	Scientific name	Storage temperature °C	°F	Relative humidity %	Highest freezing temperature °C	°F	Ethylene* production	Ethylene** sensitivity	Approximate storage-life	Observations and beneficial CA conditions
Sweetpotato, "Yam"	*Ipomea batatas*	13-15	55-59	85-95	-1.3	29.7	VL	L	4-7 months	
Sweetsop; Sugar apple; Custard apple	*Annona squamosa; Annona spp.*	7	45	85-90			H	H	4 weeks	3-5% O2 + 5-10% CO2
Tamarillo, Tree tomato	*Cyphomandra betacea*	3-4	37-40	85-95			L	M	10 weeks	
Tamarind	*Tamarindus indica*	2-7	36-45	90-95	-3.7	25.3	VL	VL	3-4 weeks	
Taro, Cocoyam, Eddoe, Dasheen	*Colocasia esculenta*	7-10	45-50	85-90	-0.9	30.3			4 months	No CA benefit
Thyme	see Herbs									
Tomatillo; Husk tomato	*Physalis ixocarpa*	7-13	45-55	85-90			VL	M	3 weeks	
Tomato, mature-green	*Lycopersicon esculentum*	10-13	50-55	90-95	-0.5	31.0	VL	H	2-5 weeks	3-5%O2 + 2-3%CO2
Tomato, firm-ripe		8-10	46-50	85-90	-0.5	31.1	H	L	1-3 weeks	3-5%O2 + 3-5%CO2
Turnip root	*Brassica campestris* var. *Rapifera*	0	32	95	-1.0	30.1	VL	L	4-5 months	
Water chestnut	*Eleocharis dulcis*	1-2	32-36	85-90					2-4 months	
Watercress; Garden cress	*Lepidium sativum; Nasturtium officinales*	0	32	95-100	-0.3	31.5	VL	H	2-3 weeks	
Watermelon	*Citrullus vulgaris*	10-15	50-59	90	-0.4	31.3	VL	H	2-3 weeks	no CA benefit
Winged bean	See Beans									
Witloof chicory	See Endive									
Yam	*Dioscorea spp.*	15	59	70-80	-1.1	30.0	VL	L	2-7 months	
Yard-long bean	See Beans									
Yucca	see Cassava									

*Ethylene production rate:
VL = very low (<0.1 µL/kg-hr at 20°C)
L = low (0.1=1.0 µL/kg-hr)
M = moderate (1.0-10.0 µL/kg-hr)
H = high (10-100 µL/kg-hr)
VH = very high (>100 µL/kg-hr)

**Ethylene sensitivity (detrimental effects include yellowing, softening, increased decay, abscission or loss of leaves, browning)
L = low sensitivity
M= moderately sensitive
H = highly sensitive

Sources of information:
Facciola, S. 1990. Cornucopia. A Source Book of Edible Plants, Kampong Publ., Vista CA. 678 pp.
Hardenburg, R., A.E. Watada, C.Y. Wang. 1986. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. USDA Agric. Hdbk No. 66. 130 pp.
Kader, A.A. et al. 1992. Postharvest Technology of Horticultural Crops. Univ. Calif. Publication 3311. 296 pp.
Kays, S.J. and J.C. Silva Dias. 1996. Cultivated Vegetables of the World. Exon Press, Athens, GA. 170 pp.
McGregor, B.M. 1987. Manual de Transporte de Productos Tropicales, USDA Agric. Handbook No. 668. 148 pp.
Maersk, Sealand and APL shipping guides
Proceedings 6th and 7th International Controlled Atmosphere Research Conferences.
Rubatzky, V.E. and M. Yamaguchi. 1997. World Vegetables. Principles, Production and Nutritive Values. 2nd ed. Chapman & Hall, N.Y. 843 pp.
Whiteman, T.M. 1957. Freezing points of Fruits, Vegetables, and Florist Stocks. USDA Mkt. Res. Rpt. No. 196. 32 pp.
Unpublished data on specialty vegetables and fruits from Marita Cantwell and Adel Kader.

Beet

USDA, Bulletin 66

Franciszek Adamicki

Adamicki is with the Department of Vegetable Storage, Research Institute of Vegetable Crops, Skiermiewice, Poland.

Scientific Name and Introduction

Beta vulgaris L. Crassa group—table beet, or red beet—is a biennial of the Chenopodiaceae family. In the first year, it forms a fleshy storage root (enlarged hypocotyl) that is edible. In the early stages of plant development, the whole plant may be consumed. Beets are grown worldwide, the top producers being Germany, Poland, the Russian Federation, and the United States.

Quality Characteristics and Criteria

Quality criteria include root shape, root size (diameter), color, firmness (turgidity), smoothness, cleanness, trimming of rootlets, and freedom from defects. Intensive and uniform color with minimum zoning is the most important quality criterion.

Horticultural Maturity Indices

Fresh-market bunched beets (with tops) are harvested as early as 50 to 70 days after planting; whereas roots (without tops) are usually harvested later but before they reach full maturity, especially when they are intended for long-term storage.

Grades, Sizes, and Packaging

Grades U.S. No. 1 and U.S. No. 2 are based primarily on external appearance. Unless otherwise specified, the diameter of each beet shall not be less than 2.5 to 3.8 cm (1 to 1.5 in). Standard bunches shall be fairly uniform in size, and each bunch of beets shall not weigh less than 0.5 kg (1.1 lb) and must contain at least 3 beets. Fresh-market bunches are packed in small crates of 10 to 15 kg (22 to 33 lb) capacity, whereas beets intended for storage are packed in 20 kg (44 lb) polyethylene-lined crates or bins of 500 to 600 kg (1,100 to 1,320 lb) capacity.

Precooling Conditions

Bunched beets should be precooled to below 4 °C (39 °F) within 4 to 6 h of harvest. Hydrocooling, forced-air cooling, and package icing are common cooling methods. Proper precooling and packaging retard subsequent discoloration of the leaves, weight loss, and decay. Mature harvested beets should be precooled within 24 h after harvest to below 5 °C (41 °F) with forced-air cooling.

Optimum Storage Conditions

Bunched beets can be kept for about 10 to 14 days at 0 °C (32 °F) and above 98% RH. Topped beets should be stored at 1 to 2 °C (33 to 36 °F) and 98% RH. During storage at 0 to 1 °C (32 to 34 °F), more black spot and rot occur than at higher temperatures (Schouten and Schaik 1980). Red beets can be in air-ventilated storage for 4 to 6 mo and in mechanical refrigerated storage for as long as 8 to 10 mo. Before storage, beets should be topped and sorted to remove all diseased or mechanically damaged roots. Large roots keep much better than small ones because they lose water and shrivel more slowly.

Red beets can be stored in pits and trenches, especially where winter temperatures are low for prolonged periods. Insulation of pits (clamps) and trenches is needed to avoid injurious temperature fluctuations. The temperature in pits (clamps) and cellars should not drop below -0.5 °C (31 °F) or exceed 5 °C (41 °F) to minimize losses caused by freezing, sprouting, and rotting.

Controlled Atmosphere (CA) Considerations

There is little or no benefit from CA or MA storage of beet roots. Elevated levels of CO_2 (over 5%) in the atmosphere may promote decay (Shipway 1968).

Retail Outlet Display Considerations

Bunched beets should be placed on refrigerated shelves at 3 to 5 °C (37 to 41 °F), and beet roots should be held below 10 °C (50 °F).

Chilling Sensitivity

Beet roots are not sensitive to chilling and should be stored in temperatures as low as possible without freezing.

Ethylene Production and Sensitivity

Beet roots produce very low amounts of ethylene, (<0.1 µL kg^{-1} h^{-1}) and are not particularly sensitive to ethylene exposure.

Respiration Rates

Temperature	mg CO_2 kg^{-1} h^{-1}
0 °C	4 to 6
5 °C	10 to 12
10 °C	16 to 20
15 °C	24 to 38
20 °C	50 to 70

Data from Uddin (1998).

To get mL CO_2 kg^{-1} h^{-1}, divide the mg kg^{-1} h^{-1} rate by 2.0 at 0 °C (32 °F), 1.9 at 10 °C (50 °F), and 1.8 at 20 °C (68 °F). To calculate heat production, multiply mg kg^{-1} h^{-1} by 220 to get BTU per ton per day or by 61 to get kcal per tonne per day.

Physiological Disorders

Death of shoots and breakdown of the top part of roots are common problems during long-term storage at 0 ºC (32 °F). Physiological disorders can appear quickly during subsequent shelf-life at 20 ºC (68 °F) after storage (Adamicki and Badełek 1997).

Postharvest Pathology

The most common decay during storage is gray mold (*Botrytis cinerea* Pers.) (Robak and Wiech 1998). Beet roots are also affected by black rot caused by *Phoma betae* Frank. Water-soaked and brown lesions become black and affect mostly the tip of the root. Good air circulation and optimal storage conditions retard development of black rot.

Quarantine Issues

None.

Suitability as Fresh-Cut Product

No current potential.

References

Adamicki, F., and E. Badelek. 1997. The effect of temperature and size of roots on storage and shelf-life of red beet. Research Report of the Research Institute of Vegetable Crops, pp. 10. The Ministry of Agriculture and Rural Development, Warsaw, Poland.

Elkner, K., E. Badełek, and F. Adamicki. 1997. The effect of cultivar and storage conditions on quality of red beet. Biuletyn Warzywniczy 46:65-78.

Hardenburg, R.E., A.E. Watada, and C.Y. Wang. 1986. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. Agriculture Handbook 66, U.S. Department of Agriculture, Agricultural Research Service, Washington, DC.

Robak, J., and K. Wiech. 1998. Diseases and Pests of Vegetable Crops, pp. 352. Plantpress Sp. z.o.o., Krakow, Poland.

Ryall, A.L., and W.J. Lipton.1983. Handling, Transportation and Storage of Fruits and Vegetables, vol. 1, 2nd ed. AVI Publishing Co., Westport, CT.

Schouten, S.P., and A.C.R. Schaik. 1980. Storage of red beets. Acta Hort. 116:25-29.

Shipway, M.R. 1968. Refrigerated Storage of Fruit and Vegetables. Ministry of Agriculture, Fisheries and Food, London, U.K.

Thompson, A.K. 1998. Controlled Atmosphere Storage of Fruits and Vegetables. CAB Intl., Wallingford, U.K.

Uddin, N. 1998. Fruit and vegetable storage and transport database. *At* http://www.postharvest.com.au/beetroot.pdf.

Zwart-Roodzant, M.H., P.S. Hak, C.F.G. Kramer, et al. 1990. Long term bulk storage of red beets in forced ventilated clamps in comparison with long term storage in mechanical cooling. Acta. Hort. 267:163-168.

Carrot

USDA, Bulletin 66

Yaguang Luo, Trevor Suslow, and Marita Cantwell

Luo is with the Food Quality Laboratory, Henry A. Wallace Beltsville Agricultural Research Center, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, MD; Suslow and Cantwell are with the Department of Plant Sciences, Mann Laboratory, University of California, Davis, CA.

Scientific Name and Introduction

Carrots (*Daucus carata* L.) are biannuals of the Apiaceae (Umbelliferae) family. The edible portion is the storage taproot, which contains high levels of carbohydrates (sugars) and ß-carotene (previtamin A). Available year-round, most of the carrots in U.S. markets are produced in California, with limited production in Michigan, Texas, Colorado, Florida, and Washington (Schaffer 2000).

Quality Characteristics and Criteria

Quality criteria vary with use. High-quality carrots are firm, straight from “shoulder” to “tip,” smooth with little residual “hairiness,” sweet with no bitter or harsh taste, and show no signs of cracking or sprouting (Suslow and Cantwell 1998).

Horticultural Maturity Indices

Harvest maturity varies with the market outlet and use. Fresh market carrots are harvested partially mature, when the roots are about 1.8 cm (0.75 in) or larger in diameter at the upper end (Kotecha et al. 1998). Late harvesting may improve storability by reducing decay during extended storage (Suojara 1999). Fresh-cut processing carrots are harvested immature to ensure they are tender and sweet.

Grades, Sizes, and Packaging

Carrots can be harvested either bunched or top-trimmed; top-trimmed is the dominant method. The common grades for bunched carrots are U.S. No. 1 and U.S. Commercial. For topped carrots, the grades are U.S. Extra No. 1, U.S. No. 1, U.S. No. 1 Jumbo, and U.S. No. 2. Topped carrots are typically packed in 0.5- to 2.25-kg (1- to 5-lb) perforated plastic “Cello-pack” bags that are grouped in 11- or 22- to 22.7-kg (24- or 48- to 50-lb) cartons or master poly bags. Bunched carrots are packed loosely in 12-kg (26-lb) cartons.

Precooling Conditions

Prompt washing and hydrocooling to under 5 °C (41 °F) are essential to maintain carrot freshness and crispness. Typically, carrots pass through several wash and flume steps that remove field heat and are then hydrocooled in chlorinated water before packing.

Optimum Storage Conditions

Storage at 0 to 1 °C (32 to 34 °F) is essential to minimize decay and sprouting during storage. High RH is required to prevent desiccation and loss of crispness. Mature topped carrots can be stored for 7 to 9 mo at 0 °C (32 °F) with 98 to 100% RH. However, commercial storage and distribution conditions rarely achieve the optimum storage conditions and topped carrots are often stored for 5 to 6 mo at 0 to 5 °C (32 to 41 °F) with 90 to 95% RH. Common “Cello-pack” carrots are typically immature and may be stored successfully for 2 to 3 weeks at 3 to 5 °C (37 to 41 °F). Bunched carrots are highly perishable due to the presence of leaves and can be maintained for only 8 to 12 days. Bunched carrots are typically shipped and stored with shaved or flaked ice.

Controlled Atmosphere (CA) Considerations

CA does not extend storage life of carrots beyond that in air with high RH (Leshuk and Saltveit 1990). Low O_2 (1%) inhibited sprouting but also promoted decay (Abdel-Rahman and Isenberg 1974). CO_2 injury appears as soft brown spots upon exposure to air. CO_2 levels above 5% promote decay. Storage at O_2 levels below 3% can result in increased bacterial rot, off flavors, and off odors (Leshuk and Saltveit 1990).

Retail Outlet Display Considerations

Carrots are often displayed loosely on a shelf with mist or in perforated plastic “Cello-pack” consumer packages.

Chilling Sensitivity

Carrots are not chilling sensitive and should be stored as cold as possible without freezing. Their freezing point is -1.2 °C (29.8 °F).

Ethylene Production and Sensitivity

Carrots produce very little ethylene (<0.1 µL kg^{-1} h^{-1} at 20 °C [68 °F]). However, exposure to ethylene (~ 0.2 µL L^{-1}) induces development of the bitter compound isocoumarin (Lafuente et al. 1996, Talcott and Howard 1999). Induction and accumulation of isocoumarin is greatest in the peel of cut carrot sections. Exposure of peeled carrot to ethylene does not result in development of bitterness. Whole or sectioned carrots should not be exposed to ethylene in storage.

Respiration Rates

Temperature	Topped	Bunched
	mg CO_2 kg^{-1} h^{-1}	
0 °C	10 to 20	18 to 35
5 °C	13 to 26	25 to 51
10 °C	20 to 42	32 to 62
15 °C	26 to 54	55 to 106
20 °C	46 to 95	87 to 121

Data from Hardenburg et al. (1986).

To get mL CO_2 kg^{-1} h^{-1}, divide the mg kg^{-1} h^{-1} rate by 2.0 at 0 °C (32 °F), 1.9 at 10 °C (50 °F), and 1.8 at 20 °C (68 °F). To calculate heat production, multiply mg kg^{-1} h^{-1} by 220 to get BTU per ton per day or by 61 to get kcal per tonne per day.

Physiological Disorders

Bruising, shatter-cracking, longitudinal cracking, and tip breakage are signs of excessively rough handling. Nantes-type carrots are particularly susceptible to mechanical damage (McGarry 1993). The severity of shatter-cracking is partially related to varietal background. Wilting, shriveling, and rubberiness are signs of moisture loss. Sprouting may occur on topped carrots if the storage temperature is too high. Bitterness can develop in storage due to the accumulation of isocoumarin, caused by disease or exposure to ethylene. Harsh flavor may be caused by high terpenoid content induced by preharvest water stress. Surface browning or oxidative discoloration often develops during storage, especially on carrots harvested when immature.

Postharvest Pathology

The most prominent storage decays are bacteria soft rot (induced by *Pectobacterium carotovora* or *Pseudomonas marginalis*), gray mold rot *(Botrytis cinerea),* rhizopus soft rot (*Rhizopus* spp.), watery soft rot *(Sclerotinia sclerotiorum),* and sour rot *(Geotrichum candidum)* (Snowden 1992). Ozone is a fungistatic against *Botrytis* and

Sclerotinia, but tissue damage and color loss occur after treatment (Liew and Prange 1994). Good sanitation during packing and storage at 0 °C (32 °F) minimizes postharvest diseases.

Quarantine Issues

None

Suitability as Fresh-Cut Product

A significant portion of fresh carrot production is used to produce fresh-cut products such as “baby carrots,” carrot coins, shreds, and sticks. Carrots directed or consigned to fresh-cut processing are typically harvested at an immature stage for optimal texture and taste. Fresh-cut carrots typically have a shelf-life of 3 to 4 weeks at 0 °C (32 °F) and 2 to 3 weeks at 3 to 5 ºC (37 to 41 °F). Superficial whitening of the cut surface (“white blush”) is caused by dehydration and remains a problem for processors and shippers (Cisneros-Zevallos et al. 1995). Low storage temperature and retention of surface moisture significantly delay development of white blush. Using sharp knives is important to reduce tissue damage and extend shelf-life (Barry-Ryan and O’Beirne 1998).

References

Abdel-Rahman, M. and F.M.R. Isenberg. 1973. Effect of growth regulators and controlled atmosphere on stored carrots. J. Agric. Sci., 53:635.

Barry-Ryan, C., and D. O’Beirne. 1998. Quality and shelf-life of fresh-cut carrot slices as affected by slicing method. J. Food Sci. 63:851-856.

Cisneros-Zevallos, L., M. Saltveit, and J. Krochta. 1995. Mechanism of surface white discoloration of peeled (minimally processed) carrots during storage. J. Food Sci. 60:320-323, 333.

Hardenburg, R.E., A.E. Watada, and C.Y. Wang. 1986. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. Agriculture Handbook 66. U.S. Department of Agriculture, Agricultural Research Service, Washington, DC.

Kotecha, P.M., B.B. Desai, and D.L. Madhavi. 1998. Carrot. *In* D.K. Salunke and S.S. Kadam, eds., Handbook of Vegetable Science and Technology, pp.119-139. Marcel Dekker, New York, NY.

Lafuente, M.T., G. López-Gálvez, M. Cantwell, and S.F. Yang. 1996. Factors influencing ethylene-induced isocoumarin formation and increased respiration in carrots. J. Amer. Soc. Hort. Sci. 121:537-542.

Leshuk, J.A., and M.E. Saltveit. 1990. Controlled atmosphere storage requirements and recommendations for vegetables. *In* M. Calderon and R. Barkai-Golan, eds., Food Preservation by Modified Atmospheres, pp. 315-352. CRC Press, Boca Raton, FL.

Liew, C.L., and R.K. Prange. 1994. Effect of ozone and storage temperature on postharvest diseases and physiology of carrots (*Daucus carota* L.). J. Amer. Soc. Hort. Sci. 119:5673-567.

Mazza, G. 1989. Carrots. *In* N.A.M. Eskin, ed., Quality and Preservation of Vegetables, pp. 75-119. CRC Press, Boca Raton, FL.

McGarry, A. 1993. Influence of water status on carrot (*Daucus carota* L.) fracture properties. J. Hort. Sci. 68:431-437.

Shaffer, E., ed. 2000. Produce Availability and Merchandising Guide. *In* The Packer. Vance Pub. Corp., Lenexa, KS.

Snowdon, A.L. 1992. A Color Atlas of Postharvest Diseases and Disorders of Fruits and Vegetables, vol. 2, Vegetables, pp. 268-293. CRC Press, Boca Raton, FL.

Suojara, T. 1999. Effect of harvest time on the storage performance of carrot. J. Hort. Sci. Biotech. 74:484-492.

Suslow, T., J. Mitchell, and M. Cantwell. 1998. Carrot Produce Facts. Recommendations for Maintaining Postharvest Quality. *At* http://postharvest.ucdavis.edu/produce_information.

Talcott, S.T., and L.R. Howard. 1999. Determination and distribution of 6-methoxymellein in fresh and processed carrot puree by a rapid spectrophotometric assay. J. Agric. Food Chem. 47:3237-3242.

Maximizing Yield and Eating Quality in Winter Squash – A Grower's Paradox

Brent Loy
Department of Biological Sciences, University of New Hampshire, Durham, NH, USA
Email: jbloy@unh.edu

Introduction

There are three major species of squash grown worldwide for their mature, edible fruit – *Cucurbita pepo*, *C. maxima*, and *C. moschata*. *C. moschata* includes the popular butternut varieties, tropical cultigens called Calabaza in the Caribbean basin, and round to oval to long neck pumpkins grown in parts of North America for processing. The species *C. maxima* includes humongous show pumpkins, Golden Delicious-type processing squash, Hubbard varieties, and the green to gray, 2 to 4 pound buttercup/kabocha varieties, the latter esteemed for their exceptional eating quality. Within *C. pepo*, acorn varieties predominate in supermarkets, but markets are expanding for 1 to 3 pound, striped, ribbed squash in the 'Sweet Dumpling' and 'Delicata' classes. Although cultural methods for the above species of squash are similar, harvesting schedules and post-harvest handling may vary considerably, along with flesh changes during storage that relate to eating quality and nutrition.

What are the key nutrients in winter squash?

Carbohydrates in the form of sugars and starch are the major constituents of squash flesh (mesocarp), comprising between 50% to as much as 70% of the dry biomass (solid portion after elimination of water) at harvest. Varieties with a high content of dry matter (18-26%)) have better eating quality than those with low dry matter content. This is because the amount of fibrous, cell wall material, mineral ash, and protein is fairly constant in most varieties, and increases in solids or dry matter, is mainly due to the accumulation of additional starch as a storage reserve (Table 1). Starch not only contributes to a desirable pasty texture of cooked squash, but also generates sugars during enzymatic breakdown.

Table 1. Percentage dry weight composition of the edible portion of buttercup and butternut squash at harvest (adapted from T.G. Phillips, 1945).

	Percent of Total	
Component	**Harvest**	**3 Months**
Carbohydrates	62-68	57-62
Starch	52-53	14-19
Sugars	10-15	43
Cell wall (cellulose, pectin)	9-10	13-17
Protein	5-6[z]	6-8[z]
Ash (mineral elements)	5-6[y]	5-6[y]
Other	10-16	8-19

[z]Values overestimated because of high soluble N content.

[y]Data obtained from other sources.

In cooking tests, high sugar content is strongly associated with high consumer rating of eating quality. The relative sugar content can be estimated using a hand-held refractometer, with values given in % soluble solids (SS). Acceptable eating quality is generally attained when SS values are 11% or higher. During storage, sugar content will increase as long as starch is not depleted. As storage time increases, the proportion of fibrous cell wall matter to total solids increases (Table 1), so texture eventually deteriorates, with flesh becoming more watery and fibrous and less pasty. This occurs faster in varieties with low dry matter because starch is more rapidly depleted during storage.

Other than providing carbohydrates and a good source of dietary fiber, the major nutritional benefit of squash is the high content of carotenoids, the yellow to orange, fat-soluble pigments. Beta-carotene, an abundant carotenoid in several varieties of squash, is an important precursor to vitamin A, an essential vitamin for human development and eye function. Lutein, a carotenoid prevalent in large amounts in some squash varieties, is one of the two principal pigments in the macular region of the retina, and increased dietary intake may reduce incidence of age-related macular degeneration. Growers can and should identify nutritional benefits of their produce as a marketing tool. Jennifer Noseworthy, a doctoral candidate at the University of New Hampshire, has found considerable variability in the types and amounts of carotenoids in different squash cultigens, especially in the species *C. moschata*, and we have developed breeding lines with nutritionally improved carotenoid profiles.

The paradox of yield and eating quality

Squash, like many crops that produce a storage organ, accumulate most leaf and photosynthetic area prior to reaching the reproductive stage. Once fruit begin to grow rapidly, vegetative growth and leaf area peaks and then begins to decline with leaf senescence. The yield capacity of a crop is largely defined by the photosynthetic capacity, the length of the reproductive period, and the proportion of the total plant biomass (dry weight of the plant) that is converted to the reproductive portion of the plant (called Harvest Index). Plant breeders can change the harvest index, and sometimes change the plant growth habit so that light is absorbed by the leaf surface more effectively. However, in modern semi-bush varieties of squash, the difference in biomass yield (dry weight yield) among varieties is largely a function of plant density or the number of plant per acre. Because grower's profits are usually a function of fresh weight yields (pounds of fruit harvested per acre), a good grower will understand what spacing and fertilizer regime is needed for producing near optimum fresh weight yields. What about variety selection? At least for wholesale markets, most growers will probably choose varieties with good fruit appearance and which give consistently high yields. So what is the paradox? Varieties with good eating quality have flesh with high dry matter, and dry matter mostly in the form of carbohydrates (starch and sugar) is a product of photosynthesis. Reproductive biomass is the product of % dry weight of the flesh x the weight of the flesh. So a poor quality variety with fruit having 10% dry matter will usually produce nearly twice the fresh weight yield of a variety that produces fruit with 20% dry matter. The double yield figure is somewhat of an exaggeration because 20 to 30% of the fruit biomass is comprised of seeds, stem tissue, placental tissue, skin and other waste tissues. Nonetheless, a grower interested in marketing the best quality winter squash, must often sacrifice fresh weight yield. This is less of a problem at a retail market because a grower can highlight a quality product and price accordingly, but with lack of quality control for squash in supermarkets, a wholesale grower has little incentive to plant a variety which has the best eating quality.

Maximize eating quality with proper harvest period

When should squash be harvested? Most of the popular edible varieties of squash have relatively small fruit size, and near full size is attained by 20 days after fruit set. Accumulation of flesh dry matter and therefore starch content peaks between 30 to 35 days after pollination. However, squash maturity can be defined as completion of seed fill which occurs about 55 days after fruit set. Rind color is not a good indication of maturity. For example, acorn squash turn a dark green, mature-looking color within two weeks of fruit set, 40 to 50 days before they should be harvested! By the same token, butternut squash turn a fairly mature tan color by about 35 to 40 days after pollination, some two to three weeks before they should be harvested. If the fruit is harvested before the seed is fully developed, then assimilates for seed fill are remobilized from the flesh to the seeds during subsequent storage. Under conditions of poor plant health or premature harvest, movement of carbohydrates from the fleshy mesocarp tissue to seeds can reduce flesh quality substantially, especially in varieties with inherently low dry matter.

Keeping track of when fruit set occurs may not realistically fit into a grower's crop scheduling, so a reasonable rule of thumb for kabocha and acorn squash is to begin harvesting squash when the ground color of the fruit (part of the fruit that lays on the soil) reaches a dark orange color. Butternut squash does not show orange ground color, so harvest should not begin until at least two weeks after squash turn tan color. Maturity dates listed in seed catalogs are often in error, especially for acorn squash, where maturity is often stated as being between 70 to 76 days when in reality the actual maturities are probably closer to 90 to 100 days. Studies in New Zealand suggest that buttercup squash harvested at 40 days after fruit set may have a harder rind and be more resistant to storage diseases than squash harvested later. However, the sugar content is low in immature kabocha squash, so I recommend harvesting prior to 55 days only when vines have begun to go down, so as to minimize sunburn damage and fruit discoloration.

Post-harvest changes affect eating quality and nutrition

In acorn and related varieties, starch to sugar conversion occurs relatively early in fruit development, and a soluble solids content of 11% or greater in the best culinary varieties may be attained within 45 to 55 days after fruit set. In butternut squash harvested at about 55 days after fruit set, we have found that about 60 days of storage at 56 to 60 ^{o}F is required for soluble solids levels to reach minimum acceptable levels. Carotenoid content often increases even more than soluble solids with storage, so squash has more nutritional value in terms of carotenoid content if stored. Kabocha and buttercup varieties fall in between the butternuts and acorns in terms of edibility at harvest. Our results suggest that most varieties have sufficient sugar levels at a 60-day harvest, but not if harvested at 40 days after fruit set.

Post-harvest changes can be accelerated with increased storage temperature, but this in turn can adversely affect storage life. Studies with kabocha squash have shown that storing squash for one week at a high temperature (85 ^{o}F) can accelerate post-harvest increases in sugar levels following subsequent storage at 54 ^{o}F. We have found that storing butternut squash in a greenhouse at temperatures of 80 to 85 ^{o}F for about two weeks after harvest will elevate SS levels to 11 to 12%

Conclusion

The three major classes of winter squash - acorn, kabocha/buttercup, and butternut – have different attributes associated with maturation and post-harvest changes in eating quality and nutrition. It is important for growers to understand these differences so as to provide information to customers that will guide them in purchasing and utilizing squash for optimum culinary and nutritional benefits. In addition to species differences in maturation, there are also considerable varietal differences with respect to eating quality. It behooves growers to become more aware of varieties which exhibit good eating quality so that their customers are satisfied with their purchases, and reap the benefits of purchasing their produce at roadside retail markets.

Pumpkin & Winter Squash

Recommendations for Maintaining Postharvest Quality

Marita Cantwell and Trevor V. Suslow

Department of Plant Sciences, University of California, Davis

Produce Facts

MATURITY INDICES

Corking of the stem and subtle changes in rind color (bright green to dull green in 'Kabocha' for example) are the main external indications of maturity. Immature fruit have a fleshy stem, maturing fruit will have some stem corking, and well mature fruit will have a well corked stem. In winter squash, such as butternut, external color changes only slightly during maturation.

Internal color should be intense and typical of the cultivar. The concentrations of the yellow and orange carotenoids generally increase only slightly during storage.

Maturity at harvest is the major determinant of internal color. Immature fruit will be of inferior eating quality because they contain less stored carbohydrates. Immature fruit will have more decay and weight loss during storage than mature fruits.

QUALITY INDICES

Pumpkin and winter squash should be full sized and well formed with the stem intact. They should be well matured with good rind development typical of the cultivar. Internal quality attributes are high color due to a high carotenoid content, and high dry weight and sugar and starch contents.

OPTIMUM TEMPERATURE

12.5-15°C (55-59°F)

Pumpkins and winter squash are very chilling sensitive when stored below 10°C (50°F). Depending on the cultivar a storage life of 2 to 6 months can be expected at 12.5-15°C (55-59°F). Research at Oregon State University showed that for 8 currently produced winter squash cultivars stored at 10-15°C (50-59°F), 90%, 70% and 50% were marketable after 9, 15 and 20 weeks, respectively.

For green rind squashes, storing at 15°C (59°F) may cause degreening, undesirable yellowing, and texture loss. The green rind squashes can be stored at 10-12°C (50-55°F) to prevent degreening, although some chilling injury may occur at the lower temperature. High storage temperature (>15°C) will result in excessive weight loss, color loss and poor eating quality.

In a UC Davis study, the best temperature for butternut squash storage for 7 months was 15°C (59°F). Besides weight loss and browning and drying of damage areas, higher storage temperatures also lead to more rapid breakdown of pulp tissue.

OPTIMUM RELATIVE HUMIDITY

50-70% with 60% usually considered optimum moderate relative humidity with good ventilation is essential for optimum storage. High humidity will promote decay. Although 50-70% R.H. will reduce decay during storage, significant weight loss will occur. For example, mature Kabocha squash lose 1.0 and 1.5% of their fresh weight per week of storage at 12.5°C (59°F) and 20°C (68°F), respectively. Weight loss of butternut squash stored at 12.5°C and 20°C was 2.5% and 5.5% per month, respectively.

RATES OF RESPIRATION

30-60 ml CO_2/kg·hr at 25°C (77°F)

To calculate heat production, multiply ml CO_2/kg·hr by 440 to get BTU/ton/day or by 122 to get kcal/metric ton/day.

RATES OF ETHYLENE PRODUCTION

<0.5 µL C_2H_4/kg·hr at 20°C

If the pumpkin or winter squash are chilled, ethylene production rates can be 3-5 times higher.

RESPONSES TO ETHYLENE

Exposure to ethylene will degreen squash with green rinds. Ethylene will also cause abscission of the stem, especially in less mature fruit.

RESPONSES TO CONTROLLED ATMOSPHERES (CA)

Atmospheres containing 7% CO_2 can be beneficial by reducing loss of green color. Yellow squash, however, appear not to be benefited by 5 or 10% CO_2 atmospheres. Lowering the O_2 concentration does not appear to provide any benefit. Univ. of Georgia research showed that storing different pumpkin cultivars at 10°C (50°F) for 2-3 months in 3% O_2 + 5% CO_2 increased the percent of marketable fruit compared to pumpkins held at ambient conditions.

PHYSIOLOGICAL DISORDERS

Chilling injury. Caused if pumpkins and squashes are stored below 10-12.5°C (50-55°F). Symptoms of chilling injury are sunken pits on the surface and high levels of decay once fruit are removed from storage. Storing fruit 1 month at 5°C (41°F) is sufficient to cause chilling injury symptoms. Depending on the cultivar, storage for several months at 10°C (50°F) may cause some chilling injury. Changes in respiration rates will precede visible chilling injury symptoms.

Freezing injury. Can occur at temperatures below -0.8°C (30.5°F).

PATHOLOGICAL DISORDERS

Several fungi are associated with decay during storage of pumpkins and winter squashes. *Fusarium*, *Pythium* and anthracnose (*Colletotrichum*) and gummy stem blight or black rot (*Didymella*) are common fungi. Alternaria rot will develop on chill-damaged winter squashes. Fruit that are overmature at harvest (>2 weeks beyond optimal harvest date) will tend to have more storage decay. *Rhizopus* may develop rapidly on fruit that have been injured at harvest.

SPECIAL CONSIDERATIONS

Curing. The fruits may have tender rinds when freshly harvested. Curing in the field, with protection from the sun by placing under the leaves, before handling and stacking into bins or wagons will help to harden or cure the rind. The recommended storage conditions also favor curing or hardening of the rind.

POSTHARVEST PHOTO GUIDE

MATURITY AND QUALITY

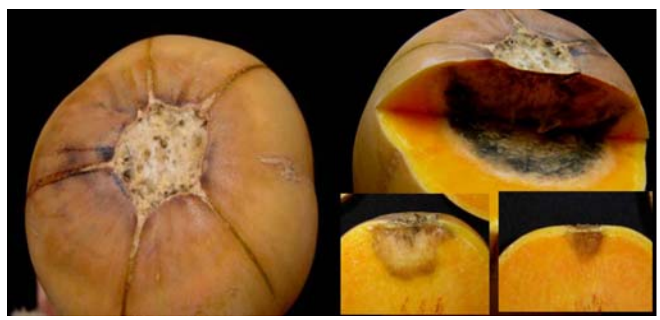
KABOCHA MATURITY

KABOCHA 3 STAGES OF MATURITY

BUTTERNUT INTERNAL COLOR

DISORDERS

BLACK ROT (*Didymella bryoniae*)



ALTERNARIA DECAY

RHIZOPUS DECAY

Continued from Page 17... "Post-Harvest Handling of Sweet Potatoes"

Curing for Quality

A portion of the annual sweetpotato crop is still marketed as "green," although the practice is fading from favor. Green roots are washed, graded, and packed within a few hours or days of harvest and shipped immediately to buyers without curing. Uncured sweetpotatoes generally lack the visual appeal, shelf life, and culinary character of cured roots.

Most sweetpotato growers and packers have invested in modern curing facilities and consider proper curing an indispensable first step in a process that allows the industry to provide a year-round supply of high-quality sweetpotatoes. Successful curing requires roots to be held at a temperature of 85°F (29°C) and a relative humidity of 85 to 90 percent with proper ventilation for three to five days immediately after harvest. (The duration varies depending on the root pulp temperature at harvest. The greater the difference between root pulp temperature and 85°F (29°C), the longer it will take to cure. See page 47 for more information.) A delay of as few as 12 hours between harvest and curing has been shown to be detrimental to successful curing.

Sweetpotatoes remain metabolically active after harvest. They respire, converting starch to sugars that are metabolized to release carbon dioxide and water vapor. Sufficient movement of air (ventilation) during curing is essential and helps dry roots and any adhering soil, provides proper oxygen and carbon dioxide exchange, and is necessary for good heat transfer during curing. As little as one-half cubic foot of outside air per bushel per day is sufficient for proper ventilation. However, sweetpotatoes injured by rough handling, exposed to chilling, or harvested from waterlogged soil may require as much as 5 to 10 cubic feet of outside air per bushel per day.

The humidity during curing should be as high as possible (85 to 90 percent) but not to the point where water may be seen on the walls, floors, bins, or especially the sweetpotatoes. All properly designed curing facilities should have correctly sized humidification equipment and controls. The cost of this equipment is easily recovered in reduced weight loss and better root quality. Curing rooms should be properly insulated to conserve energy and reduce condensation. (See Appendix 3 for a discussion of insulation materials.)

BENEFITS OF CURING:

1. Curing enhances culinary characteristics (eating quality). A sweetpotato's culinary characteristics are a combination of color, texture, taste, aroma, and fiber content. Much of the culinary character of an individual sweetpotato depends on the cultivar and, to a smaller extent, on cultural practices during the growing season. Some of the most important culinary characteristics, however, are the result of chemical changes that occur as a result of curing. Proper curing has been shown to increase the sensation of moistness and sweetness, enhance the aroma, and decrease starch content while increasing sugars.

2. Curing aids in wound healing and reduces losses due to shrinkage and disease. When roots are wounded, the exposed cells will quickly dry and die. Sweetpotatoes will naturally exude sticky latex from injuries, particularly at the ends of the sweetpotato (Figure 14). This material may dry in a few hours and appear to close the wound, but it actually provides little protection from decay organisms or weight loss. Only proper curing can result in "true" wound healing. Under curing conditions, the sweetpotato will deposit a layer of material under the dead cells in the wounded area. This barrier further reduces moisture loss and impedes microbial invasion of the tissue. In the final stage of this process, a second layer similar to undamaged skin is deposited under the wound in a process known as *suberization*.

Figure 14. Latex stains on roots. (PHOTO BY B. EDMUNDS)

3. Curing sets the skin. Freshly harvested sweetpotatoes have thin, delicate skin that is easily broken, scraped, or otherwise removed (Figure 5). Some cultivars may be washed and graded without serious injury if it is carefully done within 24 to 48 hours of harvest. However, most cultivars require curing to "set the skin" because the skin quickly becomes too loose to permit safe handling. Proper curing after harvest results in skin that sets within four to six weeks. The exact time required for skin set varies considerably across cultivars. The factors influencing skin set, such as growing conditions, are not well understood and are the subject of ongoing research.

If roots must be shipped soon after harvest, the time required for skin set may be shortened somewhat by proper curing at standard conditions followed by several weeks at proper storage temperatures but at less than 85 percent relative humidity with good air ventilation (as much as 30 to 50 cubic feet of ventilation per day per bushel may be required in this circumstance). This treatment may allow roots to be shipped sooner but will result in increased weight loss, so it is important to move this product quickly to market. For longer storage periods, follow the curing period with normal storage conditions—55°F (13°C), 85–90 percent relative humidity, and adequate ventilation.

PROBLEMS ASSOCIATED WITH IMPROPER CURING:

Inadequate and excessive curing can shorten shelf life, increase sprouting during storage, and result in excessive weight loss. Normal weight loss should not exceed 5 to 8 percent of the freshly harvested weight.

Improper ventilation during curing can result in an extremely low oxygen/high carbon dioxide environment. Exposure to this environment for short periods has been shown to reduce the effectiveness of curing, shorten storage life, and alter the taste of the sweetpotatoes, but this problem is unlikely to occur in a properly operated modern facility.

Curing at improper temperatures or humidity can reduce quality during storage. Research has shown that curing sweetpotatoes at temperatures below 75°F (24°C) increases weight loss and decreases storage life. Low humidity also results in inadequate healing of wounds.

Curing that continues for too long can result in widespread sprouting (Figure 15). It is not unusual to see short (less than one-fourth inch) sprout buds on a few roots toward the end of curing; however, widespread sprouting results in rapid weight loss. The best way to minimize weight loss from overcuring is not to exceed the recommended three to five days of curing and to reduce the temperature to 55 to 60°F (13°C) as quickly as possible. Maintaining the correct relative humidity (85 to 90 percent) during storage is also critical.

Storing for Quality

The next step in the production of quality sweetpotatoes is storage in the proper environment. The primary goal of storage is to maintain root quality and ensure an adequate supply throughout the year by minimizing both physiological disorders and disease development. Current experience shows that high-quality roots that are properly cured and held, undisturbed, under proper storage conditions—55°F (13°C), 85 to 90 percent relative humidity, with adequate ventilation—remain marketable for as long as 13 months.

These storage conditions were first determined in the 1920s with cultivars grown at that time, and recent research has shown that these conditions are still valid for modern commercial cultivars. It is important to maintain the temperature as close as possible to 55°F (13°C). Minor fluctuations of three or four degrees are expected, but avoid fluctuations of more than five degrees. Fluctuations can occur when roots are stored in common storage or in a room without temperature regulation. Fluctuations of more than five degrees will lead to premature breakdown of the sweetpotato and excessive weight loss.

Higher relative humidity (greater than 85 percent) would be entirely suitable for sweetpotato storage. However, from a practical standpoint, very high humidity (90 to 95 percent) is difficult to maintain consistently and to measure accurately. Additionally, very high humidity will cause condensation to form on the building walls or roof, causing maintenance problems and the wetting of bins and roots, which promotes decay. Improper room insulation can also contribute to condensation problems.

PROBLEMS ASSOCIATED WITH IMPROPER STORAGE CONDITIONS:

Improper storage conditions can increase the development of physiological disorders and diseases. Physiological disorders are the result of stresses related to excessive light, heat, cold, and moisture, or the mix of surrounding gases such as oxygen, carbon dioxide, and various pollutants. Some disorders can be caused by mechanical damage, and all are abiotic in origin (not caused by disease organisms) and cannot be controlled by postharvest pesticides. However, many postharvest disorders compromise the sweetpotato's natural defenses, which in turn increases susceptibility to infectious postharvest diseases. In some cases, physiological disorders may even mimic infectious diseases. Common physiological problems resulting from improper storage conditions include excessive dry matter loss, sprouting, pithiness, hardcore, chilling injury, and moisture loss (Figures 9 through 11).

Dry matter loss and pithiness. Sweetpotatoes lose dry matter through natural respiration. Respiration is a chemical process necessary for all living tissue whereby starches and sugars (dry matter) are oxidized to carbon dioxide and water vapor with the liberation of heat. The heat generated by an individual sweetpotato is negligible, but the combined output of thousands of bushels in a storage facility can raise the temperature of sweetpotatoes one-fourth to one-third degree per day. This heat must be continually removed from

Figure 15. Sprouting due to poor curing or storage conditions. Note that sprouts generally originate from the proximal end of the root (i.e., the end closest to the plant). (PHOTO BY G. HOLMES)

the facility, or the temperature will rise above acceptable levels in a short time. A storage facility must have provisions for cooling with outside air or a refrigeration system.

Although not apparent externally, significant dry matter loss may result in pithiness with the formation of many small voids (Figure 10). Pithiness is very common in sweetpotatoes held for long periods in poorly controlled storage facilities.

Sprouting in storage. Another effect of elevated storage temperatures is sprouting (Figure 15). At temperatures above 60°F (16°C), sweetpotatoes will sprout. The length of time required for sprouting depends on the temperature. It may take a month or more for sprouts to show at 65°F (18°C), but at 75°F (24°C) and warmer, sprouts can develop in a few weeks. Sprouting is always accompanied by rapid respiration and weight loss. Chemical sprout inhibitors are not used in sweetpotatoes because proper temperature control inhibits sprouting. USDA standards (see Appendix 2) list sprouts over three-fourths of an inch long as defects. Sprouts can be manually removed from roots during the packing process.

Chilling injury. Chilling injury is rare in modern storage facilities, but it can occur if roots are kept in common areas during the winter months. Storage below 50°F (10°C) can result in chilling injury that may not be evident until several weeks have passed (Figures 9 through 11).

Excessive shrinkage. If the humidity is low, sweetpotatoes will lose weight as moisture evaporates from the surface of roots. This results in weight loss and may cause shriveling of the skin, especially at root ends (Figure 16). Although some moisture loss is practically unavoidable during curing and storage, excessive water loss may be avoided by maintaining high relative humidity during storage.

Figure 16. Weight loss is increased by skinned areas and leads to shriveling. (PHOTO BY B. EDMUNDS)

TABLE 1. Typical components and sequence of components in medium and large sweetpotato packing lines.

Medium (Low Volume) Packing Line	Large (High Volume) Packing Line
dump tank	dump tank
wash/brush	wash/brush
eliminator	eliminator
grading	grading
fungicide application	**wash/brush***
sizer	fungicide application
grading	sizer 1-expanding pitch type
box fill	first grading
	wax/brush*
	sizer 2-electronic*
	final grading*
	box fill

*Bold text indicates items that differ from medium packing lines.

Disease development in storage. By far, postharvest diseases account for the greatest loss in stored sweetpotatoes. In extreme instances, decay losses can run nearly 100 percent. The occurrence of postharvest diseases tends to vary from year to year. Outbreaks occur when pathogens are given an opportunity to proliferate. Many of the diseases that affect sweetpotatoes in storage are first established in the field or on planting material such as scurf (Figure 51). Other postharvest disease organisms are wind- or soil-borne as spores and are essentially ubiquitous (such as Rhizopus soft rot).

Postharvest diseases may be caused by fungi, bacteria, or viruses, although fungi are more common in sweetpotatoes. Most viruses do not cause serious postharvest diseases, although symptoms from field infections may be first noticed after harvest (as with russet crack) or may develop in storage (internal cork). Similarly, root knot nematodes infect roots in the field, and the resulting cracking may be noticed during grading and packing (Figures 54 and 55).

Control depends on understanding disease-causing organisms, the conditions that promote their occurrence, and the factors that affect their capacity to cause losses. Additionally, following approved cultural practices in the field can significantly reduce many of these diseases. Sweetpotatoes should be inspected as they are harvested. Leave roots with indications of established disease (lesions) or obvious defects such as growth cracks or excessive skinning in the field. Gentle handling and minimization of environmental stresses can substantially reduce the level of postharvest disease. The management of specific diseases is discussed in Appendix 1.

Packing for Quality

The packing of sweetpotatoes is an industrial operation that should be dedicated to delivering the highest quality product to the consumer. The current market demands uniformity in appearance in both color and size (see cover photo bottom), which necessitates long and complicated packing lines. Unfortunately, long packing lines can increase the opportunity for skinning, bruises, cuts, and broken ends that detract from appearance and increase the possibility for disease development.

In general, good packing-line design strikes a balance between gentle, yet efficient, handling of the sweetpotatoes. Indications of the need to alter an existing packing line include high labor and energy costs, bottlenecks, congestion, worker complaints, accidents, and product damage such as excessive skinning, excessive loss to disease, and large piles of broken ends on the floor below problem areas.

An industry survey of sweetpotato packinghouses in North Carolina and Louisiana from 2004 to 2006 revealed similarities among layouts and associated trouble spots (Tables 1 through 5). Table 1 describes the typical components and layouts for mid- and large-size packing lines

Figure 17. Instrumented impact recording device used to measure impacts on packing lines. Right: fresh sweetpotato; middle: molded urethane casing with accelerometer inside; left: handheld computer with antenna for receiving signal from accelerometer and recording impacts. (PHOTO BY B. EDMUNDS)

seen in both states. An instrumented impact-recording device (SmartSpud, Sensor Wireless, Canada) was used on packing lines in both states. This device measures the force of impacts (measured as a unit of force called a *g*; 1 g = 9.81

Section Three:
Crop Storage

Table of Contents:

-Notes-

-Notes-

Crop Storage Overview and Resources

Chris Callahan, chris.callahan@uvm.edu, 802-44-7582 x256
http://go.uvm.edu/ageng
@uvmextageng / chriscallahanuvm

Introduction to Storage

Physiology - Respiration: Food is alive. Things that are alive respire. Respiration is reduced with temperature. Few crops improve once harvested.

Storage is a hotel, not a hospital.

Quality - Factors:
Appearance – Visual / Texture – Feel / Flavor – Taste and Aroma / Nutritional Value / Safety.

Ideal Post-Harvest Conditions

Post-harvest is a hotel, not a hospital. Temperature, Humidity, Air flow and air exchange (to remove ethylene). Specific to crop and some are quite different.

One of the most important tools for storage is a good thermostat. (http://go.uvm.edu/thermostats) A digital display (setpoint and present value), An output indicator (e.g. a light), A remote probe, Accurate measurement (+/- 2 F, Low differential, Ability to change mode (heating or cooling).

Humidity remains challenging to measure and control well (+/- 4% RH is common accuracy).

USDA Handbook 66 (http://www.ba.ars.usda.gov/hb66/contents.html) is a good reference for post-harvest practices by crop. The FAO guide (http://www.fao.org/docrep/009/ae075e/ae075e00.htm#table%20of%20contents) is also helpful as is the UC-Davis Post-Harvest Technology Center (http://postharvest.ucdavis.edu/).

The Crop Storage Planner may be helpful to determine zones and sizing of spaces for your specific crops. http://go.uvm.edu/cropplanner

Field Practices for Storage

Cold Chain: Movement from harvest to cool, shaded areas. Pop-up tents for extended field times.

Precooling is possible and recommended. Shade / Air movement / Cold air / Hydro and Vacuum Cooling. http://go.uvm.edu/precoolcure.

Curing if long-term storage is desired and crop indicates. Generally, a temperature and RH controlled process. USDA Handbook 66 has guidance. http://go.uvm.edu/precoolcure.

Sizing. How big to make storage? How many zones? Crop storage planner: http://go.uvm.edu/cropplanner

Refrigeration is pumping heat. Nice overview video online (https://youtu.be/gSmaXrj6u9A). CoolBots are effective and low capital solutions. www.storeitcold.com

Small heaters on thermostats are good for quick heated storage. Air exchange can be done to exploit outside cool air. http://go.uvm.edu/airexchange

Food safety – Intentional drainage to avoid standing water. Avoid spraying water on storage crops for humidity control. Smooth and cleanable finish surfaces, and clean coolers on a schedule. http://go.uvm.edu/coolerchecklist.

Construction. Insulated boxes (R-25 standard, blue-board common). Build vs. buy? Usually a wash financially when all costs are considered.

- When to build: If existing structure exists that can be built into / onto. If you have more time and skill than money. If you are positioned for donations of material and skilled time. If you want something mobile / portable.
- When to buy: If you're better at growing than building. If your pressed for time and can get something quick from the market. If insulated panels fall off a truck.

Finish surfaces. Plan for this and don't skimp. There are many options to do this well. They do cost money, but will make for a more comfortable and food-safe working environment. Smooth and cleanable. (http://go.uvm.edu/smoothnclean)

Measurement and Logging

Start with paper and pen if you have nothing else. A single roving probe thermometer is very handy as is an infrared remote thermometer. More advanced systems can be cost effective. Overview of options: http://go.uvm.edu/monitoring Summary report on trial project here: http://go.uvm.edu/wintercrops. Humidity is a real challenge to measure and control well. We have made progress with a new sensor, www.vecs.org.

Phasing and Strategic Planning

Not everything needs to be done at once. Although you may need multiple "zones" of storage, building one room and positioning the evaporator toward one corner can result in multiple "zones" without building them. Also consider local zones, you can use perforated plastic wrap for areas of high humidity, etc.

Resources:

UVM Extension Ag Engineering Blog: blog.uvm.edu/cwcallah or go.uvm.edu/callahan

Crop Storage Resources Page: http://go.uvm.edu/storage

Crop Storage Planning Tool: http://go.uvm.edu/cropplanner

USDA Handbook 66: The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks - http://www.ba.ars.usda.gov/hb66/contents.html

UC Davis Post-harvest Technology Center – http://postharvest.ucdavis.edu/

FAO - Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops - http://www.fao.org/docrep/009/ae075e/ae075e00.htm#table%20of%20contents

Thermometers:

Infrared remote – Fluke RKMT6 or similar, $59. From Grainger, et al.

Calibratable probes – Delta Trak Model 11062 or similar http://deltatrak.com/jumbo-display-digital-probe-lab-thermometer, $39.

Remote Monitoring: http://go.uvm.edu/monitoring

Storage Crops – Case Studies

Crop	Units	Carrot	Onion	Potato	Cabbage	Squash
Storage Density	lb/ft^3	22	20	42	17	35
Temp	ºF	32–34	32	36-40	32	50
RH	%	98 – 100	65 – 70	99 – 100	98 – 100	50-70
Duration	Months	7 – 9	6 – 9	Up to 12	3 – 6	1-3
Resp. rate at temp	mg CO_2 / kg - hr	10-20	3 (cured)	6 – 18 (cured)	4 – 6	100
	BTU / ton-hr	138	28	110	46	917
Ethylene Prod. Rate	uL / kg-hr	< 0.1	< 0.1	< 0.1	< 0.1	Trace
Ethylene Sensitivity	uL / L	High ~ 0.2	Low > 1500-2000	Low	High ~ 1.0	Low

UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

The University of Vermont

UVM Extension AgEngineering Blog

Thermostats for Agriculture

I am often asked by growers and processors to recommend a thermostat for greenhouse, cooler, or postharvest process use. There are many to choose from and their specifications can be confusing. It is important to remember just what a thermostat does. It is essentially no different from the light switch on the wall with one very significant exception. Instead of depending on a person to switch it from ON to OFF, we use a temperature measurement. The accuracy of both the temperature setpoint (what you set) and the actual temperature (what the actual condition is) can be critical for production quality and energy efficiency.

When asked about temperature control for use in agricultural and food processing applications, I recommend a thermostat with the following features:

- A **digital display** that provides
  - display of the actual temperature (present value, PV) the device is reading and responding to which can help troubleshoot overall system operation, and
  - display of the setpoint (SP) temperature – dial thermostats can be hard to set accurately
- An **output indicator** (e.g. a light) that tells you whether the load is being turned on or not (or, rather, that the thermostat switch is closed (ON) or open (OFF)).
- A **remote probe** that allows you to place the control unit where it is convenient to read and use and the probe where the temperature condition should actually be measured. The ability to add probe lead length should also be considered, and most sensor probes can be extended with thermostat wire up to 200 feet. A remote bulb also allows to you also move the temperature measurement point as needed. For example, you can use it to control a greenhouse bench heat system early in the spring for seedlings, then as an air temperature sensor later for tomatoes and perhaps even as a soil temperature sensor in conduit for winter growing. A remote bulb can be very helpful in food processing applications to allow temperature measurement at the center of a tank in one room with the control panel in another room.
- **Accurate measurement** over a **wide range of temperatures** ideally with the ability to calibrate it in the field, +/- 2 degF accuracy over a range from 32 deg F to 212 deg F is possible.
- **Low differential** ability, which sets the difference between turning on the load and turning it off, 1 degF differential is possible.
- **Ability to change mode**, i.e. be switched from cooling use (run a refrigeration compressor on increasing temperature) to heating use (fire a heater on decreasing temperature). This allows for standardization of thermostat on the farm and in the processing plant and the ability to move a thermostat to a different, more urgent use depending on the season or need.

Other considerations when choosing a thermostat include:

- **Compatible voltage and amperage** with the intended load, or allowance for a relay if needed. If the load is controlled with 24 VAC (some furnaces) then the thermostat should be intended for 24 VAC. If the load is intended for 120 or 240 VAC this will generally be a different model. Also be sure to check the current ratings. The DuroStat can control up to 4.5 HP (120 VAC, 30 A), Johnson Control up to 1 HP (120 VAC, 16 A), Ranco 1 HP (120 VAC, 16 A). An external relay can be added into the circuit to increase the load capacity.

- Does a **two stage thermostat** make sense? I.e., two stages of heating to control two different heaters as needed based on two “staged” setpoints. For example, a single greenhouse may have a design heating load of 350,000 BTU/hr to maintain 65 deg F . Most of the year a single 200,000 BTU/hr heater does this on a thermostat stage set for 65 degF. But on very cold days or nights a second stage set for, perhaps, 63 degF would bring a second 150,000 BTU/hr heater on to help with the load.
- Does it make sense to use **two thermostats**? This is common practice to control a heater and ventilation fans. Generally one thermostat is setup for cooling/ventilation and the other one is setup for heating. You can also accomplish two-stage heating with two thermostats set at different setpoints.
- Consider the enclosure you need. If this is for a **typical agricultural location** (e.g. greenhouse, cooler, pack house, barn) a NEMA Type 1 enclosure should be fine, if the installation area for the control box is regularly subject to directed wash water, dirt, dust or other foreign matter a NEMA 4x enclosure may be warranted. This provides some protection against personnel hazard, intrusion of foreign matter and water.
- Should you consider **pre-wired thermostat with a normal plug** to control an appliance that generally plugs into a wall. These can be helpful for turning an on/off or 0-100% dial control heater into a truly temperature controlled heater. Any thermostat can be wired this way, but for those who really prefer to avoid electrical wiring, pre-wired options are available.

Based on these features I generally suggest growers consider the following thermostats:

- Johnson Control A419/A421 – A419GEF-1 (24 VAC), A419AEC-1 (120/240 VAC). The A419 is being replaced by a newer model, the A421.
  - Model line
  - Manual
  - Installation Instructions
  - Example Sources:
    - Supply House – $88
    - Zoro – $88
    - Almost any local plumbing supply house like F.W. Webb, etc.
    - Pre-wired option. $79

Johnson Control A419

- Ranco ETC-141000-000.
  - Model line
  - Installation and Operation Manual
  - Example Sources
    - ETC – $106
    - Supply House – $112
    - Pre-wired option. $79

Ranco ETC

- DuroStat™ Electronic Thermostat
  - Installation and Operation Manual
  - Example Sources
    - FarmTek – $95
    - Growers Supply – $95
    - Pre-wired option. $79

In terms of location in a greenhouse, I suggest locating the probe centrally DuroStat
to control air temperature, horizontal air flow (HAF) fans will circulate and mix the air to "average" it out. But, as noted above, if you are controlling for bench temperature or soil temperature, then other locations are more appropriate.

If you have other thermostats you'd like to see listed and/or have other things you consider when selecting them please let me know.

Related posts:

1. **Simple DIY Outside Air Exchange (10.4)**
2. **Efficiency Vermont Incentives for Agriculture (10.1)**
3. **Calculating Greenhouse and High Tunnel Heat Loss (7.9)**
4. **Update on Heating Greenhouses with Biomass (6.5)**
5. **FIDO – A Do-it-yourself Temperature Monitor with Text Message Alerts (6.4)**

This entry was posted on Tuesday, May 3rd, 2016 at 19:45 and is filed under **Energy on the Farm**, **Equipment**, **Greenhouses**, **Heating**, **Refrigeration and Storage**. You can follow any responses to this entry through the **RSS 2.0** feed. Responses are currently closed, but you can **trackback** from your own site. **Edit this entry**.

Comments are closed.

Smooth & Cleanable Surfaces

Agricultural ENGINEERING

by
Chris Callahan
Andy Chamberlin

Finish Surfaces for Produce and Food Areas

Smooth and cleanable surfaces are an important aspect of areas where produce is washed, packed, stored and processed. Many farms are investing in renovations and expansions of these areas and are seeking materials to meet this "finish surface" need regardless of specific regulation. Meanwhile, food processing companies are often required to incorporate these materials due to regulation. This is a summary of some of the finish surface materials that are available, their pros, cons and pricing at this time.

Notes:

- These are not necessarily compliant for food contact surfaces; they are meant to be finish materials for areas where food is being washed, packed or stored. The general guidance is "smooth and cleanable." Check with the appropriate local and/or state enforcement agency to confirm applicability to your project.
- The prices listed are material cost only. The products differ in with regard to installation labor. For example, flexible sheathing like FRP will require some sort of rigid wall material to mount to where as rigid panels such as Trusscore, Extrutech and Utilite can be installed on top of furring strips. No installation costs have been captured in the prices listed.
- Links to manufacturer info are included. Most manufacturers sell via distribution channels. Check with your local building supply company for availability and current pricing. As with most materials, higher volume purchasing generally results in lower unit costs.

This cooler space was finished with Trusscore PVC panels resulting in a smooth, cleanable surface.

A properly outfitted cooler results in a clean install both visually, and physically. Note the use of trim pieces to close gaps at corners.

UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

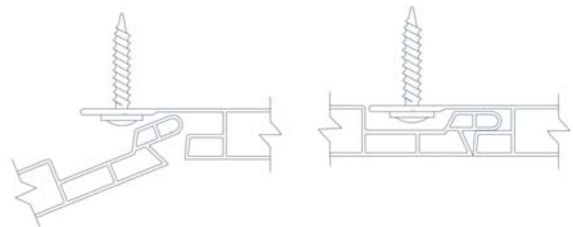
UVM Extension, Agricultural Engineering
310 Main St. PO Box 559, Bennington, Vermont 05201-0559
Office: 802.447.7582x256

Smooth & Cleanable Surfaces

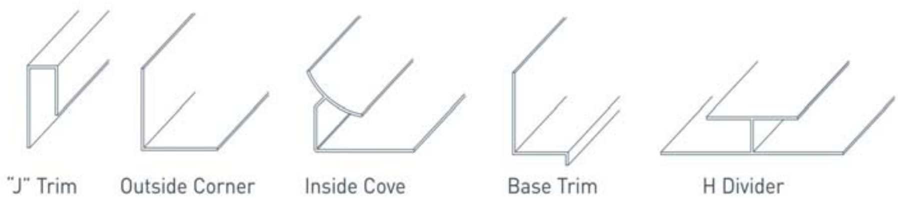
Finish Surfaces for Produce and Food Areas

Notes (continued):

- The pricing on these materials is quite variable depending on the source, when you obtain a quote, the quantity being ordered and how it is delivered. The listed price is the best information available at the time of writing. Shop around and obtain quotes from several distributors.
- Most manufacturer webpages include an easy to find, specific, installation guide for their product that will be helpful in guiding installation.



Several manufacturer's use panel locking mechanisms such as the tongue and groove system found in Trusscore. This provides for a smooth finish and hides the fastners.



Common shapes of available trim options to cover and seal all edges and seams. This keeps water from seeping behind the finish surface and entering the walls which can lead to molds and mildews and structural damage.

- FRP panels use H or J channel trim between pieces and corners which are calked in place to ensure a moisture proof seam. Follow the manufactures installation procedures.

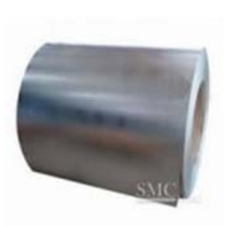
The UVM Ag Engineering website will be updated as new materials become available. Please check the site for current info. If you know of a material that should be included, please let us know.

Visit the Ag Engineering website for more helpful engineering information pertaining to farms. ***http://go.uvm.edu/ageng***

Ribcore 3' or 9' rib pattern options for ceilings

EXTENSION
AGRICULTURE

Smooth & Cleanable Surfaces

Material	Description	Pros	Cons	Material Cost ($/ft^2)
Fiber Reinforced Plastic (FRP) Textured – Class C 	Fiberglass-based wall sheathing material. Dimpled or textured surface.	Very common and familiar to trades and suppliers. Can be installed with rivets or with adhesive. Wide array of trim pieces to aid in clean installation.	Requires a backer board to install. Drilled and riveted installations can allow moisture and water leakage into wall. Consider adhesive.	$1.03
Fiber Reinforced Plastic (FRP) Smooth – Class C 	Fiberglass-based wall sheathing material. Smooth, flat surface.	Very common and familiar to trades and suppliers. Can be installed with rivets or with adhesive. Wide array of trim pieces to aid in clean installation. Smooth surface is more appealing to some due to cleanability.	Requires a backer board to install. Drilled and riveted installations can allow moisture and water leakage into wall. Consider adhesive.	$1.92
Galvalum Roofing – Ridged 	Painted, aluminum coated, galvanized steel sheets intended for roofing material but often used for wall sheathing as well.	Does not require a backing board, can be installed on furring.		$0.95
Galvalum Roofing – Flat 	Flat version of the ridged product above sheet galvalum sheathing. (see p.25 of linked manual)	Does not require a backing board, can be installed on furring. Flat surface may be easier to clean for some.		$0.76

EXTENSION
AGRICULTURE

Smooth & Cleanable Surfaces

Material	Description	Pros	Cons	Material Cost ($/ft^2)
Trusscore Paneling 	PVC twin-wall plastic panels in 16" widths, and available in a variety of lengths.	Does not require a backing board, can be installed directly on studs		$1.52
	Find more info at: http://www.trusscore.ca 1-888-418-4679			
WallTuf Paneling 	Recycled PVC-based wall sheathing.	Considered more environmentally benign than FRP panels.	Requires a backer board to install. Drilled and riveted installations can allow moisture and water leakage into wall. Consider adhesive.	$1.25
	Find more info at: http://www.palramamericas.com/Products/Flat-Sheets/WALLTUF 1-610-285-9918			
Extrutech Twinwall 	PVC twin-wall plastic panels	Does not require a backing board, can be installed on furring.		$2.20
	Find more info at: http://www.epiplastics.com 1-888-818-0118			
Utilite Paneling 	Polypropylene twin-wall plastic panels	Does not require a backing board, can be installed on furring.		$1.85
	Find more info at: http://www.nudo.com/p_utilite_wall.php 800-826-4132			
Ribcore 	PVC ribbed panels Used for ceilings	Will not rust or rot		$0.77
	Find more info at: http://www.ribcore.info 888 773-3130			

EXTENSION

AGRICULTURE

Rats & Other Rodents

Agricultural ENGINEERING

by
Chris Callahan and
Andy Chamberlin

When considering storage rooms, wash and pack sheds with growers there is one topic that is sure to strike a nerve: RODENTS.

This document is intended to provide summary information about measures you can take to reduce crop losses from these pests. It is the result of a review of current literature on the topic and feedback from the Listserv of the Vermont Vegetable and Berry Grower's Association (VVBGA). This document includes both **active measures** (traps, rodenticides, FSMA compliant cats and ball pythons, etc.) and **passive measures** (sealing, doors, packing, hardware cloth, novel construction, accepting the loss, selling everything early).

But why are these creatures so challenging? Here's some background[1]:

House Mice Can

- Enter openings larger than 1/4 inch
- Jump as high as 18 inches
- Travel considerable distances crawling upside-down along wire
- Survive and reproduce at a temperature of 24°F if adequate food and nesting material are available.

A rat approaching a baited trap.

Rats Can

- Crawl through or under any opening higher or wider than 1/2 inch
- Climb the outside or inside of vertical pipes and conduits up to 3 inches in diameter
- Jump from a flat surface up to 36 inches vertically and as far as 48 inches horizontally
- Drop 50 feet without being seriously injured
- Burrow straight down into the ground for at least 36"
- Swim as far as 1/2mi in open water, dive through water traps in plumbing, and travel in sewer lines against a substantial water current.

As one grower put it, "To deal with rats, you've got to think link a rat!"

Bottom Line

Cleanliness and Sanitation – Keep food sources well contained and sealed up, reduce "harborage" (places they can hide and live including weeds around the edge of a building), minimize available standing water. In short, make it unappealing and uncomfortable for them.

Rodent Deterrent Construction – Keep them out of the building. [References 1-3 provide very detailed guidance and novel, passive and relatively inexpensive construction ideas] Some examples from the references include keeping all wood products like cardboard, roots, or lumber off the ground and away from the building. Installing proper drainage with sand, stone and proper slope away from your building helps reduce moisture which can carry other pests like beetles and termites. Think about your exterior landscaping and its ability to trap moisture against the building. Keeping grass and weeds trimmed won't leave a place for rodents to hide and travel. Think about all possible points of entry, sills, doors, windows, roofs. Mice can sneak into small holes and cracks so do your best to seal up all possible points of entry.

A well-cleared base-board / ground interface. Minimal space for harborage.

Excessive weed growth allowing ample cover and harborage.

Population Reduction — Bait, trap, kill.

Using snap traps, sticky pads, poisonous bait are all the most effective ways of dealing with a rodent problem [References 5 -7].

UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

UVM Extension, Agricultural Engineering
310 Main St, PO Box 559, Bennington, Vermont 05201-0559
802.447.7582 x256

2017 10 10

EXTENSION

AGRICULTURE

Rats & Other Rodents

Responses from the VVBGA LISTERV

The following are responses from Vermont growers. These are some of their challenges and solutions related to rodents on their farms.

- I have had over 20% of my sweet potatoes damage by voles. Usually the largest sweet potatoes are the ones half eaten. The next year I put five “yard windmills” in the sweet potato bed, 100 ft. long, along with a half stick of gum under the black plastic by each plant – cheap gum from the discount food store. Both were done after I removed the row covers and before the vines spread. That reduced the damage to less than 5%. Very anecdotal and empirical data but worth exploring. Supposedly the voles do not like vibration of the windmill and eating the gum gives them a bellyache, if fatal I do not know. Bigger windmills, four inches in diameter and larger, with metal post seem to work better. How much gum is actually needed I do not know. A SARE grant in your future.

“Tomcat” Traps are easy to set & easy to empty.

- Not the cheapest retrofit, but have had the best luck with making all walls tin or concrete, and having rat traps permanently set at every overhead door jamb, since the seal is not 100%. Ventilate with in-wall intake and exhaust fans instead of opening doors.

Rodent bait near a doorway close to the floor.

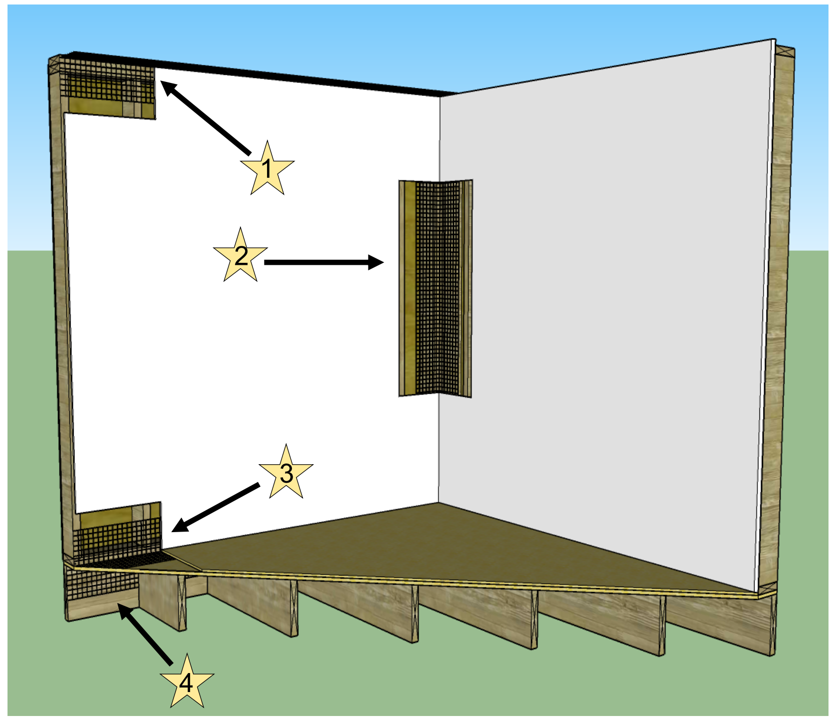
- I recently tried the tin cats and was happy. Baited them by putting small amount of oats in the trap and tilting it so the grain slid to the end where the screen was. After the mice got a few seed through the screen, they were drawn into the trap to get the remainder. Two mice in the same trap on the first night. The downside is that you have to clean out all the grain each time so it doesn’t hamper the trap mechanism. Have used Contract waxy block in bait stations for at least 4 years. Switching to a different bait because I think they are starting to get a resistance.

Traditional snap-traps are often effective.

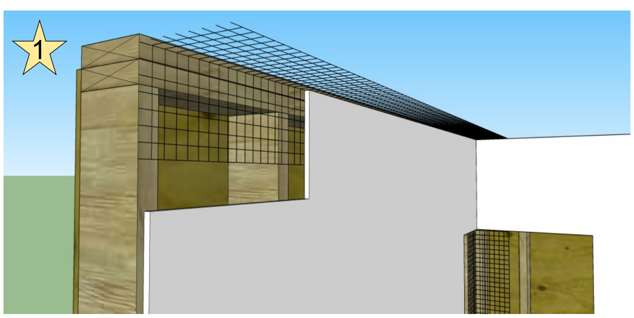
Rats & Other Rodents

Responses from the VVBGA LISTERV (cont.)

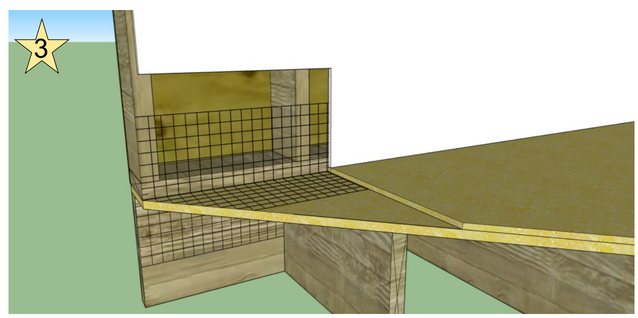
- I've been using that old root cellar all winter for 3 years now without any rodent problems. The process of having someone cement hardware cloth over every crack and crevice was time-consuming but really seems to have worked. I think I finally got rid of the rats in my toolshed through a combination of trapping and disturbing their nesting spots. I'm curious about rodent solutions that apply to the field and high tunnel. I've tried to keep cats but the fishers get them.
- I have not had a single animal in the new barn that I built with the 12" concrete knee wall. I partly contribute the success to the fact that I do not set the bins on the ground. They are filled on the trailer and go directly from the trailer to the barn. This reduces the chance that a hitchhiker will take a ride into the barn.



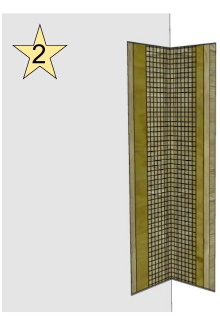
Possible places to install "hardware" or "wire" cloth (1/4" mesh) to deter rodents at potential entry points.



At the corner of wall & ceiling.

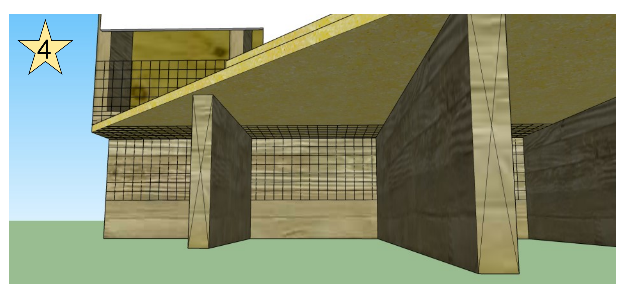


At the corner of wall and the floor. Can be done above or below floor.



- Hardware cloth can be stapled in place and covered with sheathing or finish surfaces.
- Hardware cloth may be placed behind sheathing or between sheathing and finish surface in the case of a retrofit.
- Bending the cloth prior to placement eases installation.

At inside corners of walls.



Installing below floor, between each joist and the floor may be necessary as a retrofit.

UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the United States Department of Agriculture. University of Vermont Extension, Burlington, Vermont. University of Vermont Extension, and U.S. Department of Agriculture, cooperating, offer education and employment to everyone without regard to race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital or familial status.

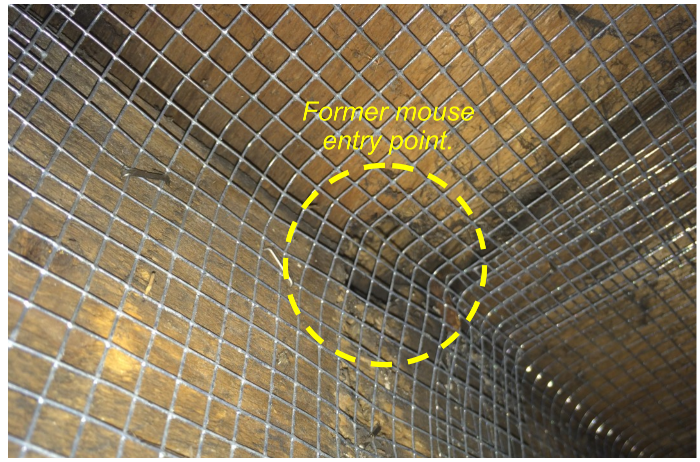
EXTENSION

AGRICULTURE

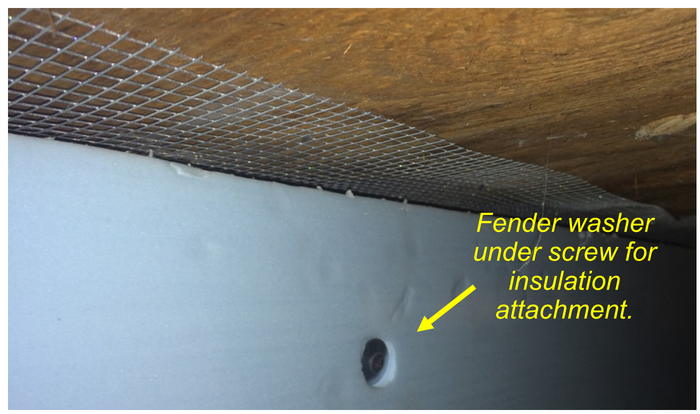
Rats & Other Rodents

Responses from the VVBGA LISTERV

- We are a very small pumpkin farm and don't have the storage needs for food, but I use lots of snap traps and dump those little, dead vermin bodies while wearing a happy smile!
- We have only killed rats by accidentally moving a pallet onto one. Can't bait them. They are very intelligent.
- "We have a great barn cat and a Jack Russell terrier for our farm."
- Mice – kernel of corn wedged into mouse trap trigger covered in peanut butter. Rats – same as above but do not the set the trap for several nights and remove all other food sources (in chicken hutch empty all food containers) then set the trap. Putting a milk crate over the trap prevents chickens, cats, dogs from getting caught. Also works with chipmunks, and occasionally with red squirrels. Voles – hard to trap, run them down and stomp.



Hardware cloth between the joist and the floor.



Finished installation, underfloor without finish surface.

REFERENCES

1. Baker R., Bodman G. and Timm, R. 1994. **Rodent-Proof Construction and Exclusion Methods. The Handbook: Prevention and Control of Wildlife Damage.** Paper 27. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1025&context=icwdmhandbook
2. Hoddenbach, G., Johnson, J., Disalvo, C. 1997. **Rodent Exclusion Techniques. A Training Guide for National Park Service Employees.** National Park Service. http://www.ehs.ucsb.edu/files/docs/eh/ihrodentexclusion.pdf
3. Simmons, S. 2005. **Pest Prevention Construction Guidelines and Practices.** CASBO Journal. http://www.cdpr.ca.gov/docs/pestmgt/pubs/casbo_article.pdf
4. UMass Extension. 2008. **Rodent Control on Farms.** Fact Sheet – https://ag.umass.edu/sites/ag.umass.edu/files/fact-sheets/pdf/RodentControl08-44.pdf
5. University of Maryland Extension. 2014. **Rodent Control on Small Poultry Farms.** Fact Sheet. https://extension.umd.edu/sites/default/files/_docs/publications/FS-985%20Rodent%20control%20on%20small%20poultry%20farms.pdf
6. Pierce, R. 1982. **Bait Stations for Controlling Rats and Mice.** Fact Sheet G-9444. University of Missouri Extension. http://extension.missouri.edu/p/G9444
7. Vantassel, S. M., Hygnstrom S. E. and Ferraro, D. M. 2012. **Bait Stations for Controlling Rats and Mice.** Fact Sheet G1646. https://wildlife.unl.edu/pdfs/bait-stations-controlling-rats-mice.pdf.

COMMUNITY | 4-H & YOUTH | ENVIRONMENT | AGRICULTURE | FOOD

UNIVERSITY OF VERMONT EXTENSION

CULTIVATING HEALTHY COMMUNITIES

Farm Cooler Checklist

Whether your winter storage rooms are getting bare or you are making the transition from sweet corn to potatoes, what better time to do a good cleaning and even sanitizing than now?

Housekeeping - Start by emptying the room and removing all visible debris with sweeping or vacuuming. Next scrub with an appropriate detergent soap and rinse according to the cleaner's label. A final step of sanitizing surfaces according to the sanitizer's label may be prudent and could improve storage quality and food safety. If you've used water to rinse, wash or sanitize, be sure to allow time and air flow (and maybe even some heat) for complete drying before packing the cooler again.

This is also a good time to check over the construction and make some simple repairs that are not so simple when tons of produce are in the way. Some examples of maintenance items might include; finally connecting that evaporator drain so it doesn't drip condensate on the bin below, replacing damaged paneling and insulation to prevent rodent visitation and heat gain, replacing exposed light bulbs with shatter proof fixtures or energy efficient upgrades (http://go.uvm.edu/effvtag), or sealing up corners or other areas. More details are provided below and a quick reference checklist is provided on the reverse.

Smooth, clean and shiny, this CoolBot™ cooler used TrussCore™ twinwall PVC as a finish surface.

Finish Surfaces – How clean can you get the inside of your storage room? If you currently have untreated plywood or chipboard, think about upgrading to a smooth, cleanable surface (http://go.uvm.edu/smoothnclean). These finish materials make the space a whole lot easier to keep clean, can help prevent plant pathogens in storage, can improve food safety and make the space more pleasant to work in.

Envelope Check – You can improve energy efficiency, increase storage quality and reduce rodent damage by maintaining a solid envelope around your storage room. While you're cleaning, check all door seals to be sure they are in good repair and are functioning well. Replace worn rubber seals, make door closer and latching adjustments to ensure a proper seal, close the whole room up while standing inside with the lights off and look for daylight around the door or other areas. Seal those spots up. Any gaps in your sheathing or other holes in walls, corners, etc? Seal them up. Obvious signs of rodent intrusion should get extra attention and rodent control measures (http://go.uvm.edu/rats) should be taken.

Equipment Check – Now is a good time to make sure your refrigeration and other temperature control equipment is working as planned.

Connections - Check any visible electrical wiring and refrigerant lines. Any significant wear or obvious damage that should be repaired now? Are refrigerant lines still well-insulated?

This cooler has no floor drains. Instead the evaporator drain is plumbed to a bucket that is emptied according to an SOP.

Inside – Check the evaporator (the place the cold air comes from). Can you see through the fins clearly in every channel (you may need to shine a light from the opposite side)? Is the drain pan clean and free of debris? Is the drain connected to piping or hose and directed to the floor, a bucket or an outside drain? Is the drain clear, clean and functioning properly?

Outside – Are the compressor (generally a black cylindrical part) and condenser (radiator and fan) clean and clear of debris? Grass, leaves, dirt, etc. should be removed from the equipment. Condenser (radiator) fins should be cleaned with a vacuum and even pressure washed to provide for effective heat removal and improved energy efficiency. Is there good air movement possible around the condenser? Is this the year to put a roof on the compressor and condenser?

CoolBots™ (http://go.uvm.edu/coolbot) – Check the pitch of the AC unit. It should be pitched slightly to the outside and there should be a drain hole at a low point to allow water to drain out of the bottom. Are both heat exchangers clean and clear of debris and dust? Is there a good seal around the AC unit to prevent air infiltration? Does your AC unit have a "vent"? Check to be sure it is set in whatever position you want. Venting (or fresh air) will bring in some outside air which is good for higher ethylene producers or crops seeking lower RH storage. Otherwise, the vent should be closed. Also check your CoolBot wiring and especially your fin sensor to be sure they are securely fastened and in position.

Operation - Power up the system and adjust your thermostat to force a call for cooling. Inside - Are all evaporator fans coming on as they should? Is the unit producing cold air? Outside – Is the compressor coming on when there is a call for cooling? Is the refrigerant hot where it should be (between the compressor and the condenser or outside heat exchanger) and cold where it should be (going back inside to the evaporator)?

CoolBots – Does the AC unit power up? The fan should be blowing air. The compressor should come on within about 30 seconds. The CoolBot control should power up and indicate your setpoint and current temperature. Does the AC unit produce cold air?

Controls / Thermostats – Is your thermostat as tired as you are? Does it allow you precise control of temperature? Is now the time to upgrade or replace it (http://go.uvm.edu/thermostats)?

UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

Farm Cooler Checklist

Lighting – Do you have functioning lights? Is now a good time to add them in? How about an automatic occupancy switch so they turn on or off automatically when your hands are full of that awesome produce? Have you considered shatter-proof lighting fixtures? Or energy efficiency upgrades (http://go.uvm.edu/effvtag)?

Plan for a Full Room – Think about last year's storage season and what you had a hard time reaching when you needed it. Can you change your loading this year to make access easier? Also remember that you likely have a variety of conditions in your storage room with the coldest, driest, highest airflow zone being close to the evaporator and the warmest, most humid, still zone being at the end furthest from the evaporator. Does your planned loading take that into account? Should crops be relocated to accommodate optimal storage? Any other lessons learned from last year that you can take action on now? Should you consider building additional storage space now to accommodate any expanding production?

CHECKLIST

Cleaning and Sanitizing

- ❑ **Empty** storage room completely.
- ❑ **Sweep / vacuum** inside of storage room from floor to ceiling.
- ❑ **Clean** inside surfaces of storage room with an appropriate cleaner or detergent, following manufacturer's label instructions.
- ❑ **Sanitize** inside surfaces of storage room with an appropriate sanitizer, following manufacturer's label instructions.
- ❑ **Dry thoroughly**. Allow time, provide ventilation and consider heating slightly to ensure complete and thorough drying after cleaning, sanitizing and/or rinsing.
- ❑ **Upgrade or Repair Finish Surfaces** to ensure a solid, smooth, cleanable interior. (http://go.uvm.edu/smoothnclean)

Envelope

- ❑ **Inspect** envelope for damage, cracks or other openings and seal as needed.
- ❑ **Check for daylight** from the inside with the door closed and lights out. Note and repair any worn seals or other places where light comes in.
- ❑ **Adjust door closers and latches** for a secure seal when closed.
- ❑ **Check for signs of rodents** or other pests and make necessary changes to prevent them. (http://go.uvm.edu/rats)

Equipment

- ❑ **Inspect power wiring** and outlets or junction boxes for wear or other items needing repair. Take care to ensure power is off during this check.
- ❑ **Confirm or install working lights.** Consider efficiency upgrades to lighting and using an occupancy switch. (http://go.uvm.edu/effvtag)
- ❑ **Check insulation** and ensure good general condition of refrigerant lines.
- ❑ **Clean evaporator fins** to be sure air can move freely through them. You should be able to see clearly through each channel when a light is shown from the other side.
- ❑ **Clean evaporator drain pain** and look for signs of blockage (e.g. standing water, sediment, mold, etc.)
- ❑ **Ensure evaporator drain is functioning**, connected from pan to an intentional outlet (floor, bucket, outside drain, etc.) and allowing water to flow freely as intended.
- ❑ **Clear the compressor and condenser** (outside) of leaves or other debris.
- ❑ **Clean the condenser (radiator) fins** with a vacuum and/or pressure washer.
- ❑ **Protection the compressor and condenser** from the elements with possible a shed roof, etc.

Operation of Cooling

- ❑ **Confirm thermostat operation**, set a low temperature on the thermostat and listen for the "click" of a relay or note the output indicator light. Consider whether a thermostat upgrade is appropriate. (http://go.uvm.edu/thermostats)
- ❑ **Check operation of evaporator fans (inside).** Do they come on uniformly when the unit is powered up (or when summer cooling mode is selected)? Is the unit providing cold air? Evaporator fans are often a key efficiency upgrade that is likely supported by Efficiency Vermont (http://go.uvm.edu/effvtag).
- ❑ **Check operation of compressor and condenser fan (outside)**. Is the compressor running when there is a call for cooling. Is the condenser fan running. Are refrigerant lines hot between the compressor and the condenser and cold going back to the evaporator inside? You may also want to explore an upgrade of compressor and condenser for improved efficiency (http://go.uvm.edu/effvtag).
- ❑ **Heaters** - Note, these same checks can be used for heated spaces when applied to a heater.

CoolBots™ - (http://go.uvm.edu/coolbot)

- ❑ **Pitched down and out**, allowing for evaporator water to drain away toward the outside.
- ❑ **Ensure the drainage hole is open and clear** allowing water to drain.
- ❑ **Ensure both heat exchangers are clean** (inside / evaporator and outside / condenser).
- ❑ **Set the AC vent** according to whether you want outside air makeup or not.
- ❑ **Check location and condition of temperature sensors**, especially the fin sensor.
- ❑ **Check the seal around the AC unit** in the wall to make sure it is sound and preventing air infiltration.
- ❑ **Check operation of the unit** by forcing a call for cooling.

Capacity and Planning

- ❑ Do you have all the storage space you need for the coming year? Time for a quick expansion or a new zone?

Contact: Chris Callahan. UVM Extension, Agricultural Engineering. 802-773-3349. chris.callahan@uvm.edu. blog.uvm.edu/cwcallah.