Cold Cellars for Year-Round Local Food and Farming

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Vision: *Cold cellars are a common economical low energy tool for families and farms to increase the local availability of nutritious, flavorful food.* They are used in a wide variety of sizes from basement cold closets to buried containers to walk in cinder block or poured concrete buried cellars to drive in below ground warehouses. When needed, early and late season cooling is provided by refrigeration or the use of ice made during winter and held in insulated storage.

Definition: *Cold storage place for root crops (potatoes, turnips, carrots, beets, etc): a pit or underground cellar used for storing vegetables and fruit.* The common name root cellar is used because the primary cold storage was for root crops such as potatoes, beets, carrots, turnips, rutabagas, etc. The intent of using the term "cold cellar" in place of "root cellar" is to convey a broader use – it is not just for "root" crops. Generally it is different than a cooler or refrigerator since an electrical refrigeration is not used. However, for best quality and for larger farm storage capacity, a refrigeration unit may be installed for early fall cooling or for use during the summer. Cold cellars can be used to reduce the use of refrigeration which can be one of the largest food and farming energy uses and therefore contributor to climate change.

Desired Learning Outcomes:

- Identify individual and family goals for use of cold cellars or closets.
- Identify farm and local food system goals for use of cold cellars.
- Identify and review available educational resources.
- Identify which crops are suitable for cold storage cellars and what conditions are necessary.
- Identify methods and costs of construction and sources of funding for cold cellars.
- Determine what necessary educational resources are needed, what information is not available and needs to be either searched out or discovered though research.

Cold Cellar Topics – Seven C's to help the memory learn the story.

1. Concepts

1.1. Basic methods of risk management for the small scale farm include: 1) build soil quality and organic matter, 2) increase crop and production diversity, 3) extend the production and marketing season and 4) use direct marketing methods that cultivate customer loyalty.

1.2. The cold cellar is a simple, affordable, low energy tool for improved human nutrition, food security and farm profitability through extension of the production and marketing. It is comparable in many ways to a hoophouse/passive solar greenhouse for season extension. It is a tool that makes time and can allow rapid payback of a moderate investment. Eliot Coleman describes the hoophouse, the root cellar and the compost heap as three keys to farm success for the twenty first century. The combination of extended season production and diverse methods of preservation (storage, canning, freezing, pickling, fermentation, drying, etc) provide a foundation for a healthy, thriving culture of local food.

1.3. The basic concepts of the underground cold cellar are the same as for hundreds of years. The year round temperature of the earth at depths of 6 to 12 feet is typically in the range of 40 to 50 F with minimal seasonal fluctuation. The insulation of a buried cellar with 18-24" of soil on the roof can together with proper maintenance of moisture and ventilation can provide an ideal environment for storing living produce such as leaf, root, seed and fruit vegetables. The added idea here is that with the combination with a limited amount of refrigeration to cool the cellar earlier in the fall season and possibly during the summer months the value becomes even greater. The cold cellar can have other valuable uses in addition to storage.

1.4. Multiple approaches are available including:
  1.4.1. The basement cold closet built in the house and ventilated with cold outside air to maintain a lower temperature. Ventilation can be passive or with thermostatically managed fans.
  1.4.2. Wooden or plastic container(s) can be buried in accessible areas and mulched to provide access during the winter. Fifty gallon barrels and residential refrigerator or freezer compartments have been used for in ground storage.
  1.4.3. Walk in cinder block or poured concrete buried cellars, often built into a slope or hillside.
  1.4.4. Larger facility with doors and access suitable for driving in with a forklift or tractor and wagon; a below ground warehouse.
1.5. The MSU Student Organic Farm has operated a 48 week Community Supported Agriculture (CSA) program for six years. Distribution during the winter months includes fresh leafy greens and root crops from the passive solar greenhouses (PSGH) and produce from storage. Primary storage items include potatoes, onions, cabbage and carrots from a 40F and mod/high humidity cooler and winter squash and garlic from a 50F low humidity cooler. Energy cost and contribution to our carbon foot print are significant and could be reduced with a root cellar.
1.6. Paul and Sandy Arnold in New York built a 20' x 30' concrete block basement below a storage and work building when they first started their farm ~20 years ago. In recent winters they have stored over $75,000 in produce for sale at winter farmer's markets.

2. **Crops**
  2.1. What to grow? See vegetable production chart provided. See storage condition list provided.
  2.2. Cultivar selection can be very important. Longer season cultivars – less stored water.
  2.3. Timing of harvest later in the season is important.
  2.4. Quality of the produce to be stored is also very important. Needs to be as blemish free as possible. Produce is sorted and the best is stored and blemished or damaged material is sold or processed. Freshly harvested crops with appropriate moisture content are expected to store best.
  2.5. Many root crops are best stored without being cleaned or washed. Carrots may be an exception based on soil type and possible "staining" of the roots.

3. Conditions
  3.1. How to store it?
    3.1.1. The produce is still alive – stored carbohydrates of energy is consumed in the presence of oxygen and produces heat and carbon dioxide. To maintain the proper "living" conditions, at least three variables need to be considered: temperature, humidity and ventilation.
    3.1.2. Temperature: Most cold tolerant or cool season crops will store best between 33 and 35F or just above freezing and up to 40F. Warm season crops sensitive to chilling injury (tomatoes, cucumbers, etc) are typically stored at temperatures above 50F unless processing, cooking or eating will occur shortly after removal from storage. The temperature needs to be actively monitored and managed and will vary with the quantity of produce in the space.
    3.1.3. Humidity: Most root and leafy crops will store best at high humidity (+80%) or moisture levels. Root crops like carrots need to be stored in some moist medium to maintain quality. Some crops like onion, garlic and winter squash store better at low humidity level (less than 60%). Moisture may need to be added by wetting the floor or walls with water depending on the construction methods.
    3.1.4. Ventilation: Reasons for ventilation include: 1) removal of heat of respiration, 2) replenishing the oxygen supply, 3) removing volatile compounds from the produce that may effect flavor or sprouting like ethylene. The greater the density or amount of produce in the space, the more ventilation is needed. Ventilation or air tubes need to be planned prior to construction and place during construction.
    3.1.5. Common storage categories are 1) cold dry, 2) cold moist, 3) cool dry, 4) cool moist.

3.2. **Storage Conditions for Selected Fruits** and **Vegetables**

3.2.1. **Cold and Very Damp (Moist) (**32-40°F and 90-95% relative humidity) Beets, Carrots, Celeriac, Celery, Chinese cabbage, Hamburg rooted parsley, Horseradish, sunchokes, Kohlrabi, Leeks, Parsnips, Rutabagas, Salsify, Scorzonera, Turnips, Winter radishes

3.2.2. **Cold and Damp (Moist)** (32-40°F and 80-90% humidity) Apples, Cabbage, Cauliflower (short-term), Endive, Escarole, Grapefruit, Grapes, Oranges, Pears, Potatoes, Quince

3.2.3. **Cool and Damp (Moist)** (40-50°F and 85-90% humidity) All short-term: 1-4 weeks: Cantaloupe, Cucumbers, Eggplant, Sweet peppers, Ripe Tomatoes, Watermelon

3.2.4. **Cool and Dry** (35-40°F and 60-70% humidity) Onions, Garlic, Green soybean pods (short-term)

3.2.5. **Moderately Warm and Dry** (50-60°F and 60-70% humidity) Green tomatoes (up to 70°F), Dried Hot peppers, Pumpkins, Sweet potatoes, Winter squash;

3.3. For garlic, onions and winter squash a warm (70-80F) and low humidity (50-70%) curing phase of 7 to 28 days will increase the longevity of storage. The curing can occur in a barn or a ventilated greenhouse.

3.4. For sweet potatoes (75-85F) or potatoes (65-75F) a warm and moist curing period of 7 to 10 days can allow for thickening of skin or repair of damage to the skin during the harvest.

3.5. The humidity in a cooler with refrigeration is typically lower than the humidity in a root cellar without refrigeration.

3.6. How long will certain crops store? Varies from weeks to months.

3.6.1. Longer term (3 to 6 months): cabbage, carrots, garlic, onions, potatoes, winter squash;

3.6.2. Medium term (1 to 2 months): beets, Brussels sprouts, celery, Chinese cabbage, turnip;

3.6.3. Short term (1 to 3 weeks): cauliflower, cucumber, eggplant, melon, peppers, tomato;

4. Construction

4.1. Where? Ease of access, utilities, water drainage, rocks, groundwater;

4.1.1. Often built where there is a slope so that three sides are easily buried with the access door on the sloped side. The door is typically not facing south to reduce sunlight exposure which can lead to undesired heating. Drifting of snow should also be considered.

4.1.2. In flat areas with no slopes, a cold cellar could be built at ground elevation and then either heavily insulated or covered with soil to provide a structure easily accessible to vehicles.

4.2. How? Insulated and ventilated closets or interior rooms can be constructed in cool areas of a house, a basement or an outdoor storage building. For above ground rooms built in storage barns, a source of heat may be necessary to prevent freezing. Ventilation with cold air is important for keeping the space cold or cool.

4.3. How? Buried containers such as trash cans or barrels are a common, low cost cold storage method. For deep (>24") containers, placing the container on the side with access from the side may be easier to fill and empty than a vertical orientation with access from the top. Refrigerators and freezers with the mechanical refrigeration and coolant gasses removed (not released into the atmosphere) can be buried and easily accessed through the hinged door.

4.4. How? Walk in cellars - at least three construction options with concrete for larger units:

- Pour cement footer and then build walls with concrete block units (CBU) (cinder blocks) cemented together with mortar. Cost estimate would be around $1 per block to buy the block and $2-$3 per block for construction. A 12' x 16' cellar 9 blocks high took about 600 block.
- Build a form for the walls and fill it with poured concrete – usually done by a company that specializes in this construction. Steel reinforcing rods are important and add to the cost.
- Purchase precast sections of cement and or water storage or handling units and have it delivered and put in place. Heavy equipment is needed to set pieces in place.

- For all three methods, the roof can be made with precast cement panels set in place; polyethylene film is often used over the top to prevent water drainage from above. A perimeter drainage line is often installed to divert and drain the water from above.

4.5. Multiple rooms are an advantage to provide either variable temperature or moisture conditions or to keep ethylene producing crops separate from vegetables damaged by ethylene. For example, apples and potatoes or carrots are not recommended to store together due to ethylene from the apples. (Although there are reports of this being done without negative consequences.)

4.6. It is important to plan for ventilation pipes or openings so fresh cold air can be drawn in and existing air can be exhausted. The ends of the pipes need to be protected so they are not buried by snow or open to insects. Accelerator fans for heating ducts can be managed with thermostats to activate when the inside air is too warm and the outside air is cold.

4.7. Usually a double door to provide insulation with a dead air space. Interior doors can be made with foam board panels. Door needs to be protected from drifting snow.

4.8. Refrigeration can be added for early fall cooling and extended season use. Refrigeration is more difficult in a high humidity environment due to ice formation on the cooling coils. The system needs to be designed to operate in high humidity conditions.

4.9. Costs? How much does it cost?

4.10. Sources of funding? – Normal farm lending agencies. The USDA Farm Service Agency has supported workshops for hoophouses and expressed an interest in providing loans. Examples of profitable us of cold cellars may stimulate future loan possibilities.

5. **Considerations** -

5.1. The cellar needs active, routine management of temperature and inspection of crops to rapidly remove any decaying produce.

5.2. Cooling - early fall precooling – either by ventilation at night or on cold days or with refrigeration. May also be needed in early spring; the produce is alive and respiring which leads to heat – more produce means more heat and perhaps need for cooling or ventilation.

5.3. Ventilation and Gasses: Carbon dioxide - ventilation – ethylene – some ventilation is required.

5.4. Relative Humidity and Water: Adding with a hose or buckets of water or removing moisture by ventilation.

5.5. Another option for extending cooling in the spring is to make blocks of ice and store them in an insulated room

6. Containers

6.1. How to efficiently move crops in and out by hand or with equipment. Recommendation is to have a plan prior to construction so the size of the cellar or rooms will allow efficient space use.

6.2. Stacking bagged (usually mesh or perforated plastic film) produce or containers on pallets is on option. Wooden bushel or bulk boxes or plastic bulb or milk crates are also used.

6.3. Produce stacked around perimeter with access in the middle or with an additional stack in the middle with a narrow walkway between.

6.4. How will the crop be marketed?- moving small or large quantities in or out at one time?

6.5. Shelves can be used to improve access and to take advantage of stratification in the cellar with warmer temperature higher and cooler temperature lower.

7. Combinations – The cold cellar space can have multiple other uses.

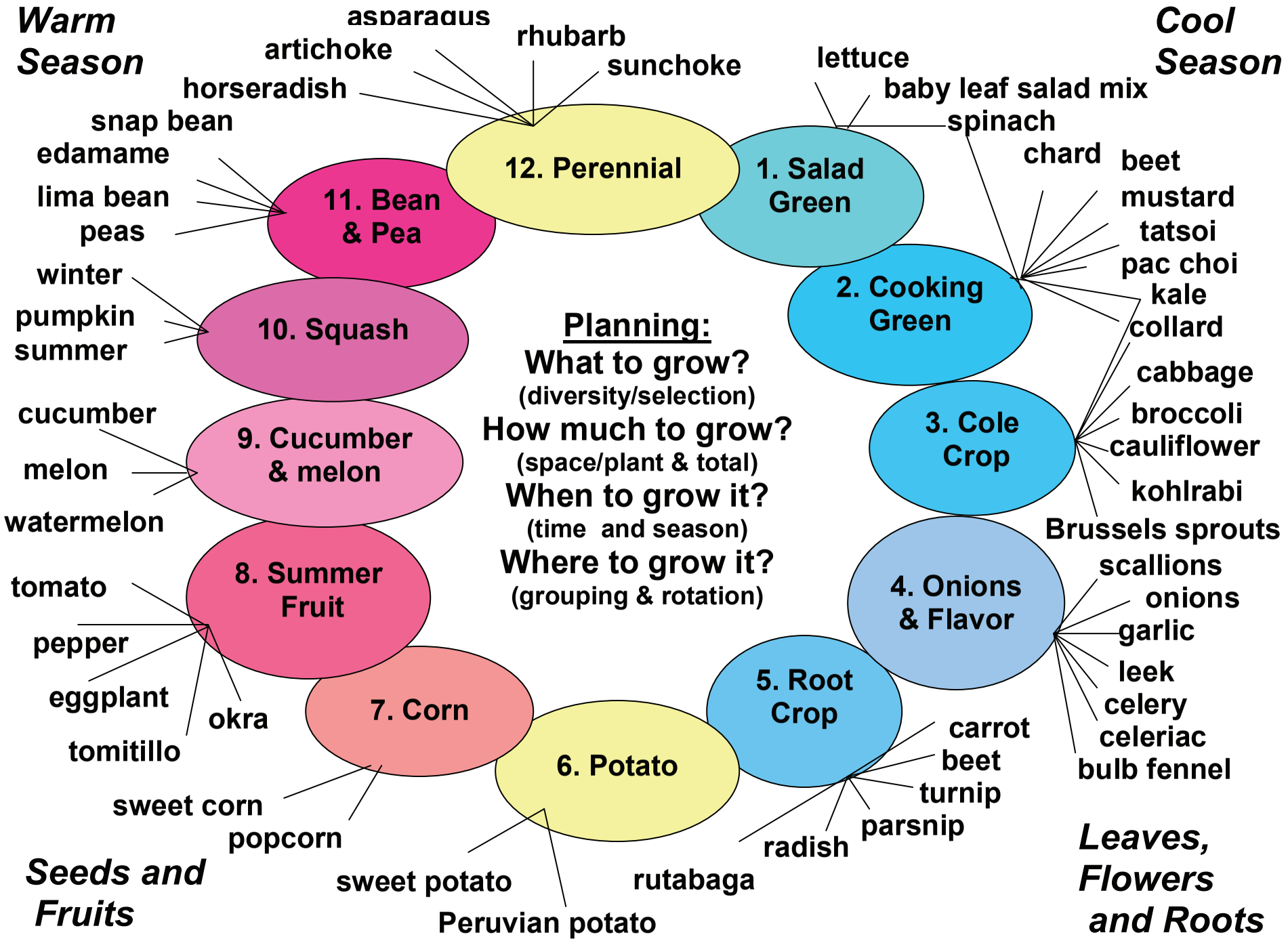
7.1. Holding or refrigeration for crops during the summer. The root cellar may warm to 60-65F during the summer months depending on the depth and the amount of ventilation. Crops harvested early morning and without excessive field heat can be held and quality preserved. Chilling sensitive summer fruits like tomatoes, peppers, cucumbers, summer squash, eggplant, etc will do better at this temperature than in a 40F refrigerator.

7.2. Warming air for winter passive solar greenhouses. Make use of digging a deep hole by placing air tubes in the soil beneath the cold cellar to warm very cold outside air to a temperature of 40-50F to help keep a hoophouse or small greenhouse from freezing. Could use solar electric to operate fans for venting the root cellar or the greenhouse. Could pull warm air full of carbon dioxide from the cellar into the greenhouse and replace the cellar air with fresh cooler air.
7.3. Store or thaw compost or root medium for spring transplants if you don't have a greenhouse.
7.4. Use the cold cellar as a foundation for a storage or work building above.
7.5. Use the cold cellar for mushroom culture on logs or in bags on shelves.
7.6. The future will bring opportunities for aquaculture – raising fish and shell fish – and a moderated temperature environment or an insulated one may be an efficient place for production that does not require light.
7.7. Some fermentation processes like the production of sauerkraut and stored fermented or pickled produce do better at cooler temperatures like those expected in the cold cellar.

Sources of Information:
Root Cellaring: Natural Cold Storage of fruits and vegetables by Mike and Nancy Bubel is highly recommended by almost all authors that have addressed the topic in the last 30 years. It was first published in 1979 with a second edition in 1991. Storey Books (http://www.storey.com/) published and sells the book http://www.storey.com/subcategory_listing.php?cat=Food&subcat=Preserving as a great value at $15. Following is a brief outline of the topics.

1. Growing the right crops for storage.
    a. Variety selection
    b. Scheduling for late harvest
2. Harvesting high quality produce and preparing it for storage.
    a. Recommended stage of development and harvest methods.
    b. Pretreatment to insure maturity of winter squash, onions, potatoes, garlic, etc.
3. Specific crop storage recommendations or uses.
    a. Vegetables
    b. Fruits (ethylene considerations)
    c. Other: eggs, pickled or fermented foods, mushroom production, root media for transplants,
4. Construction
    a. Small buried containers
    b. Basement root closets
    c. Excavated cold cellars
5. Personal experiences
6. Recipes

Eliot Coleman – *Four Season Harvest* has a chapter on root cellars. A web (Google) search with "root cellar" or "root cellars" turns up many unrelated sites because the phrase is also used as a name for organizations. Several very good articles are available from Mother Earth News:
http://www.motherearthnews.com/Real-Food/1991-08-01/Root-Cellaring.aspx Bubel Year-round (4 pg)
http://www.motherearthnews.com/Modern-Homesteading/1985-09-01/Installing-Root-Cellar.aspx (8pg)
http://www.motherearthnews.com/Modern-Homesteading/1980-07-01/Root-Cellars.aspx
http://www.motherearthnews.com/Green-Homes/2004-12-01/Build-a-Basement-Root-Cellar.aspx
http://www.motherearthnews.com/Organic-Gardening/1983-07-01/A-Flatlanders-Root-Cellar.aspx
http://www.motherearthnews.com/Do-It-Yourself/1974-09-01/The-Parthenon-of-Root-Cellars.aspx
pallet root cellar http://theepicenter.com/tow1102.html
http://www.grit.com/home.aspx


Warm Season
Cool Season
asparagus
artichoke
horseradish
rhubarb
sunchoke
lettuce
baby leaf salad mix
spinach
chard
beet
mustard
tatsoi
pac choi
kale
collard
cabbage
broccoli
cauliflower
kohlrabi
Brussels sprouts
scallions
onions
garlic
leek
celery
celeriac
bulb fennel
carrot
beet
turnip
parsnip
radish
rutabaga
Peruvian potato
sweet potato
popcorn
sweet corn
okra
tomitillo
eggplant
pepper
tomato
watermelon
melon
cucumber
summer
pumpkin
winter
peas
lima bean
edamame
snap bean
12. Perennial
1. Salad Green
2. Cooking Green
3. Cole Crop
4. Onions & Flavor
5. Root Crop
6. Potato
7. Corn
8. Summer Fruit
9. Cucumber & melon
10. Squash
11. Bean & Pea
Planning:
What to grow?
(diversity/selection)
How much to grow?
(space/plant & total)
When to grow it?
(time and season)
Where to grow it?
(grouping & rotation)
Seeds and Fruits
Leaves, Flowers and Roots