Root, Tuber & Bulb Crops

- Carrot & Relatives
  - Umbelliferae Family (Parsley Family)
- Beet
  - Chenopodiaceae Family (Goosefoot Family)
- Radish, Turnip, Rutabaga & Horseradish
  - Cruciferae Family
- Sweet Potato
  - Convolvulaceae Family (Morningglory Family)
- Potato (Irish potato)
  - Solanacea Family (Nightshade Family)
- Jerusalem Artichoke
  - Compositae Family (Sunflower Family)
- Onion, Leek & Garlic
  - Alliaceae Family

Carrot

- *Daucus carota* var. *sativus*
- Biennial, Cross pollinated (sometimes severe inbreeding depression)
- Cool season crop (<85°F)
- Center of Origin: Afghanistan
- Originated from 'Queen Anne's Lace'
- Believed that when carrot brought to North America, at least one plant reverted to wild type and escaped to become weed

Early cultivated carrots were "red", yellow, white and purple, with red probably the most common

Wild carrot **Early cultivated carrot**

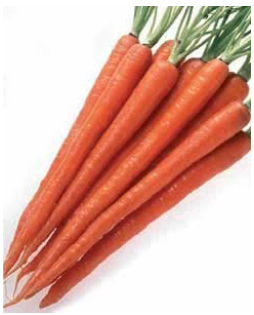
Orange carrots were selected by breeders

- Yellow selections replaced "red" carrots sometime after the 12th century (yellows still widely cultivated in Western Asia)
- Orange carrots were bred in the mid-1700s in The Netherlands, and quickly became the choice carrot in Europe

Carrot Types: Imperator

Imperator: Long (8-10") with narrow shoulders that taper smoothly toward the tip

Uses: Most common fresh and "cut-and-peel" processed; late maturing with good storage usually grown in winter



Carrot Types - Danvers

Danvers: Medium length (usually ~6") with broad shoulders that taper toward the tip

Type first developed in Danvers, Massachusetts in 1870s

Uses: Fresh and processed; good quality for both, but tend to become woody with age Grows in heavier and shallow soils better than the longer Imperator types

Carrot Types - Nantes

Nantes: Medium length (~6") with cylindrical shape (almost no taper) and rounded ends

Originated in Nantes, France

Uses: Fresh; early maturing and can be grown in late spring for summer crop

Carrot Types - Chantenay

Chanenay: Medium to short length (~5") with broad shoulders that taper toward the tip

Originated in Chantenay, France

Uses: Primarily processing; grown in summer, lighter in color and coarser in texture than other types. Shorter length will tolerate heavier soils than other types

Carrots can be an excellent source of

Anthocyanins - β-carotene - Lycopene

Carrot Industry

- Fresh Market: ~76% of total production
- Processing: ~24% of total production
- Many States produce substantial acreage of carrots

Plant Growth & Development

- Carrot is a biennial grown as an annual
- Root is an enlarged taproot that accumulates starch and sugar
  - Mature roots have two distinct regions:
    - Inner core of mostly xylem and pith
    - Outer core of secondary phloem and periderm
      - Sugars, β-carotene higher in phloem than xylem
      - Fibers more prevalent in xylem than phloem

Temperature Requirements

- Optimum temperature for growth and development: 60°-70°F
  - Temperatures <55°F tend to make roots longer and more slender and paler (less carotene)
  - High temperatures can cause stronger flavor and coarse texture
- Post-juvenile plants (>¼") can be vernalized by temperatures <45°F
  - Will bolt if followed by warmer temperatures

Soil Requirements

- Grow best in deep, loose, well-drained sandy loam soil
- Heavy clay soils tend to produce more leaves and forked roots
  - Can be managed with accurately regulated irrigation
- Stones, heavy clods, other obstructions can cause misshapen roots

Crop Establishment

- Can only be direct seeded
  - Transplants will always result in forked roots
- Optimum germination temperatures: 50°-85°F
- Seedling growth is weak, so soil crusting must be managed
- Plant spacing affects root shape & development
  - Increased spacing = larger roots (processing)
- Will benefit from raised beds (deeper, warmer, drier soil)

Cultural Practices

- Weed control is critical because young, slow growing plants cannot compete with weeds
- Require an evenly distributed water supply
  - Generally require a weekly irrigation
  - Fluctuations in water can cause cracking

Pests & Diseases

- Major problems:
  - Pests or diseases that affect roots
- Root-knot Nematodes:
  - Cause swellings (galls) inhibiting them from their normal function, resulting in forks & deformities
- Wireworms, grubworms, others:
  - Feed on roots
- Aster Yellows:
  - Multiple tops & multiple hair-like roots emerging from shrunken taproot
  - Virus transmitted by leafhoppers

Harvesting

- Can harvest at any edible size
- Processing crop: ~1-½" diameter at shoulder
- Fresh market: ~¾"-1-½" diameter at shoulder
  - Usually younger stage than processing crop
- Generally, smaller carrots are more tender & juicier
- Usually mechanically harvested, except for bunching carrots (tops left attached for marketing); harvesters remove tops during harvest

Postharvest

- Optimum storage conditions: 32°F 98-100% RH
- Shelf-life:
  - Mature, topped: 7-9 months
  - Immature, bunched (with tops): 2-3 weeks
  - Immature, topped: 4-6 weeks

Nutritional Value

- Highest content of carotenes (α & β)
  - β-carotene is cleaved in the human body to create two Vitamin A molecules
  - α-carotene yields one molecule
  - One 7" long carrot contains ~270% of the RDA for Vitamin A
- But this is only valid for carrots with orange color

Diversity of carrot compounds

Parsnips

- Carrot relative with same features (Umbelliferae, biennial, out-crosser)
- *Pastinaca sativa*
- Generally minor crop, but considered the "medieval potato"
- Culture requirements essentially the same as carrot, except not as heat tolerant; best grown at 60-65ºF
- Cool temperatures (near freezing) at maturity convert starches to sugars, resulting in increased quality
- Parsnip seed is short-lived, usually not more than one year

Salsify

- Compositae family (Sunflower)
- Cool season biennial
- *Tragopogon porrifolius*
- Oyster plant (flavor)
  - Black rooted types technically referred to as Scorzonera, but not a common name
- Culture similar to parsnip/carrot
- Cold temperatures tend to sweeten the root

Scorzonera

Salsify

Salsify Flowering – Typical Composite

Beet

- Chenopodiaceae Family
  - Spinach family
- *Beta vulgaris* var. Crassa
  - Same species as Swiss Chard & Sugar Beets
- Cool season biennial, cross pollinated (wind)
- Center of Origin: Europe, North Africa, West Africa (Mediterranean Region)
- Relatively new crop (var. Cicla is very old)

Beet Industry

- Relative small production (~118,000 tons)
- Processing: ~60%
  - Mostly Wisconsin & New York
- Fresh Market: ~40%
  - Texas leads the US
- Small market for pigment extraction

Climatic Requirements

- Note: All enlarged roots are storage organs
  - Maximum yield and quality will occur when growth conditions allow for excess energy manufacturing in the plant beyond what is required for normal growth & development
- Optimum temperatures: 60-65^{o}F, but will tolerate warmer temperatures
- Temperatures >50^{o}F for 2-3 weeks will vernalize
- Heavy soils or crusting will reduce germination/emergence

Plant Growth & Development

- Storage root develops as alternating rings of conductive tissue and storage tissue (zoning)
- Compound: betalains
  - Different from anthocyanins
    - Contain Nitrogen
  - betaine (red)
  - Suppressed at high temperatures (leads to increased zoning)
- Poor growing conditions leads to small fibrous roots

Crop Establishment

- "Seed" is actually a dried fruit containing 2-6 seeds (Seedball)
- Usually direct seeded, but may be transplanted for an early crop
- Plant spacing ~1", but wider (2-3") when also used for greens
- May require hand thinning because of seedball

Pests & Diseases

- Diseases usually not a major problem for beet production (other than damping-off)
- Insects include leaf miners, cutworms, aphids & leafhoppers
- Physiological Disorders
  - Black spot: Caused by Boron deficiency.
    - Beets have generally high micronutrient requiremtents
  - Poor root formation: Overcrowding
  - Woody roots & poor coloring: inappropriate environment

Harvesting & Postharvest

- Harvest when they reach desired size:
  - Fresh market: usually 1-½ to 2-½" diameter
  - Processing: usually when 40% are over 2"
  - Root size is controlled primarily by spacing and cultivar, not by maturity date
- Harvest & handling similar to carrot
  - Machine harvest & topped
  - Bunched beets harvested by hand
- Shelf-life: 4 – 6 months @ 32oF and 98-100% RH (topped)
  - Bunched beets: 10-14 days at same conditions

Crucifer Rooted Crops

- Radish, Turnip, Rutabaga & Horseradish
- Culture very similar to other Crucifer crops, but some key differences

- Radish (*Raphanus sativus*)
  - Easy to grow (Greek *raphanos* means "easy to grow)
  - Cool season, fast-maturing
  - Biennial, cross-pollinated
  - Center of Origin: China

Radish

- Minor commercial importance, but extensive in home gardens
- Types:
  - Spring: Typical round, red radish
  - French Breakfast: Elongated spring type
    - 25-30 days to maturity
  - Daikon: Elongated white
    - 40-50 days to maturity
  - Winter: Multiple shapes and colors, usually larger, more elongated & later maturing
    - 50-60 days to maturity

Planting & Culture

- Will grow well under crowded conditions
  - 8-10" rows, sometimes 3-4 seed per inch for early maturing types
  - Later maturing types generally 2-3" apart
- Require high fertility due to rapid growth
  - Reduced or checked growth results in tough, woody, pithy & pungent roots

Diseases & Pests

- Most of insects & diseases of other Crucifer crops also affect radish
  - More susceptible to nematode damage because the root is the product
- Physiological Problems:
  - Cracks & splits: overmature
  - Small roots, off-flavor: temperature too high (~80^{o}F maximum for maturity)

Harvest & Postharvest

- Commercial crops machine harvested just like beets & carrots (lifted and topped)
  - Once over harvest
- Bunching radishes are hand harvested

•Shelf-life:
  - –Summer types: 2-3 weeks @ 33oF & 95-100% RH
  - –Winter types: 3-4 months at same conditions (with tops removed)

Turnips & Rutabagas

- Two closely related species in terms of cultural and culinary characteristics
- Turnip: *Brassica rapa* Rapifera group
- Rutabaga: *Brassica napus* Napobrassica group (also called "Swede turnips)
- Center of Origin: Europe/North Asia
- Biennials, cross-pollinated, cool season
  - Optimum root development at 40-60^{o}F
- Rutabagas slightly larger than turnips
- Turnips mature in about 2 months, while rutabagas may take 3 months

Planting & Culture

- Similar to carrots & beets, except not as exacting in requirements
- Turnips usually grown as fall and spring crop in the South, while rutabagas typically grown as a fall crop in the North
- Typically direct seeded, 3-4" apart for turnips & 4-8" for rutabagas

Diseases & Pests

- Most of insects & diseases of other Crucifer crops also affect turnips & rutabagas
- More disease & insect problems than radish because of longer time in the field
- Physiological Problems:
  - Bitter, off-flavors: Conditions that result in slow growth or stress

Harvesting & Postharvest

- Best quality when "medium" sized
  - Turnips: 2-3" diameter
  - Rutabagas: 3-4" diameter
- Often said that best quality comes from crop harvested after a light frost
- Turnips often machine harvested like carrot & beet
- Rutabagas not usually machine harvested
- Shelf-life: 4-6 months at 32o-35oF & 90-95% RH (topped)
  - May be coated with wax to prevent dehydration

Horseradish

- Crucifer family
- Armoracia rusticana
- Perennial, grown as an annual, cross pollinated, warm season (not too cold or hot)
- Center of Origin: Southern Europe
- Used as processed condiment for meats & fish
- Unique pungent aroma and taste comes from the sulfur compound allyl isothiocyanate (possibly anti-carcinogenic)
  - If exposed to air, pungency is rapidly lost after being ground or processed

Planting & Culture

- Grows best when warm in the early season, and cool in late season
- Early growth is concentrated on foliage under warm temperatures, moving to root growth in late summer and fall under cool temperatures
- Vegetatively propagated from secondary roots of previous crop (trimmed from previous harvest)
- One-year-old secondary roots (6"-18" long) are planted 4"-5" deep 18"-24" apart
- The "sets" are slant cut on bottom end and straight cut on top end, and planted at a 45º angle, with the top end elevated
- Commercial production is highly developed

Culture

- To obtain straight roots, growers sometimes us a procedure known as "lifting":
  - The crown is pulled slightly out of the soil and the upper side roots and outer leaves are removed, and then pushed back down and covered with soil
  - Procedure usually done twice during the season
  - Procedure is expensive though, and only done where a premium is paid for straight root
- Weed control is difficult since crop is grown on so few acres and hardly any herbicides are labeled for use

Diseases & Pests

- Although a crucifer crop, diseases and pests are few, possibly because crop is high in certain phytochemicals and is grown on so few acres

Harvest & Postharvest

- Harvest after tops killed by frost
- Commercial crop is mechanically lifted from the soil and hand loaded
- May also be allowed to overwinter in the field and harvested in early spring
- Shelf-life: Several months at 30-32°F and 98-100% RH, but usually not an issue since usually processed within a few weeks of harvest
- Roots harvested when actively growing will not store as well as those conditioned by cold temperatures

Sweet Potato

- Only important food crop in the Convolvulaceae family (Morning-glory)
- Ipomoea batatas
- Center of Origin: Tropical America
- Warm season, perennial grown as an annual
- Very important source of carbohydrates for much of tropical and sub-tropical world
- Edible root contains about 27% carbohydrate and high concentrations of carotenes and other nutrients
- Fresh sweet potatoes provide ~50% more calories than Irish potatoes

Types

- Soft-fleshed
  - Deep yellow-orange color, sweeter and moister than firm-fleshed types
  - Sometimes called “Yams” although the true yam is a different genus (*Dioscorea*) grown only in tropical climates
- Firm-fleshed
  - Yellow skins with white, yellow or light orange flesh

Industry

- Produced in 30 States, but commercially important in 10 mostly Southern States where crop is a main food source
  - North Carolina, Louisiana, California, Mississippi, Alabama, Texas, Georgia & South Carolina
- World-wide production is significant in most tropical regions
  - Africa leads in acreage, but China is the largest producer, with over 80% of world-wide production

Cimatic & Cultural Requirements

- Warm season, not frost tolerant
  - Optimum growth: 70°F soil temperature and 85°F air temperature
    - Minimum soil temperature: 59°F
    - Damage results under prolonged air temperatures <50°F
- Soil types are critical for high yields of quality roots:
  - Very light soils produce low yields of high quality roots
  - Heavy soils produce high yields of low quality roots
  - Best balance of yields & quality come on well-drained, sandy loam or silt loam soil

Planting & Crop Establishment

- Vegetatively propagated
  - Transplants ("Slips")
    - Produced from seed roots
    - Adventitious shoots that are removed from the seed root and rooted
    - Most common in US
  - Vine cuttings
    - Common in tropics
- Spacing will affect root size (plant spacing, not row spacing)
  - Best economic yields usually with 12" spacing, but later cultivars are usually planted farther apart
- Soil aeration is required and usually obtained by bedding the rows (8"-10" high)

Weed Control

- Good weed control is critical early in development, but once the vine has spread, sweet potatoes will normally suppress further weed growth

Cultivars

- Since sweet potatoes are vegetatively propagated, you would expect great uniformity for a given cultivar
  - But this is not often the case, as a great deal of variation occurs even between slips from the same root stock
  - Yellow and red skinned potatoes have been found on the same plant
  - Variability attributed to spontaneous mutations
    - Sweet potato has a higher than normal mutation rate
    - Most mutations are deleterious
- Growers typically practice selection in the field

Diseases & Pests

- Sweet potato has few insect pests
  - Sweet potato weevil an exception
- Nematodes can cause losses of roots
- Several diseases
  - Black Rot (fungal disease different from crucifer disease)
    - Most destructive; can occur during propagation, on plants in the field, and on roots in storage
  - Scurf
    - Fairly unique to sweet potatoes; no apparent injury to above ground plant, but produces a brown to black discoloration to the skin, eventually causing root shrivilling
  - Storage diseases
    - Can be unique to stored roots, or may be a field disease that continues to develop while in storage

Harvesting

- Sweet potatoes will continue to grow as long as the plant stays green
- Harvest is made when highest percentage of roots are at the desired size
- Usually occurs about 130 to 150 days after planting

•Harvest usually made by mechanical digging and hand loading

•Vine removal necessary prior to mechanical digging

•Sweet potatoes have a thin skin and are susceptible to damage which may lead to disease development in storage

Postharvest

- Proper curing critical for long shelf-life
  - 80-85°F and 85-90% RH for 4-7 days
    - Promotes the formation of cork layers on wounded surfaces
- Storage: 55-60°F, 85-90% RH
- Shelf-life: 4-7 months, with some cultivars keeping for one year
- Some sugar will convert to starch in storage, and an average of 2% weight loss will occur
- Susceptible to chilling injury below 55°F, resulting in discoloration, internal breakdown and off-flavors when cooked