Vegetables - definition

Webster’s definition of “vegetable”

“A usually herbaceous plant (as the cabbage, bean, or potato) grown for an edible part that is usually eaten as part of a meal; also: such an edible part.”

(Legally defined under the tariff act of 1883; declaration that import duties be collected for vegetables but not for fruits)

Vegetables - other features

• Generally cultured as annuals
• Mostly propagated from seed
• Many are insect pollinated
• Variable adaptation to climate and environment
• Most require intensive management
• Production acreage is usually small
• All contribute vitally to the human diet

Gary Larson
“Early vegetarians returning from the kill”

Nutrition

• Two Important Nutritional Facts:
  1) All foods come directly or indirectly from plants.
Two Important Nutritional Facts:

1) All foods come directly or indirectly from plants.

2) Two-thirds of the world’s population rely on a largely vegetarian diet.

**Macronutrients:**
- carbohydrates
- fats
- essential fatty acids
- proteins

**Factors affecting nutrients in plants:**
- Genetic background
- Growing environment (including pests, diseases)
- Storage conditions:
  - A crop’s nutrient content is highest at harvest.
  - Minimal losses with proper storage temperature and humidity.
**Nutrition – Vital Crops**

- **Carbohydrate**
  - white potato
  - sweet potato
  - dry beans
  - cassava
  - yam
  - taro (aroids)
  - plantain

- **Fat**
  - mature seeds of some legumes
  - and cucurbitas

**Nutrition – Vital Crops**

- **Protein**
  - beans
  - peas
  - sweet corn
  - potato
  - leafy crucifers

- **Pro-Vitamin A**
  - carrot
  - squash
  - green leafy vegetables
  - pepper
  - orange/yellow flesh
  - sweet potato

**Nutrition – Vital Crops**

- **Vitamin C**
  - crucifers
  - immature bean seed
  - tomato
  - bean sprouts
  - pepper
  - white potato
  - melons
  - many leafy vegetables

- **Minerals**
  - crucifers
  - most other leafy veggies

**Plant Families with Toxicants**

- **Asteraceae – Lettuce** – nitrates and alkaloids
- **Brassicaceae – Crucifers** – goitrigenic and cholinesterase inhibitors
- **Chenopodiaceae – beets, spinach** – oxalic acid, saponins, nitrates
- **Fabaceae – Legumes** – allergens, cyanogenic glycosides, hemmaglutinins, etc

**Origin, Evolution**

- Nikolai Ivanovich Vavilov

Most of the varietal wealth in our crop plants was concentrated in eight great centers of diversity:

China, Hindustan, Central Asia, Asia Minor, the Mediterranean region, Abyssinia, Central America, west-central S. America
Fig. 2.1 Centers of Origin

Origin, Evolution

- Nikolai Ivanovich Vavilov

Centers of origin of species coincide with the areas where the greatest diversity exists in the species.

Video time:
http://www.youtube.com/watch?v=WQz5Ib72XbE

Secondary centers of origin (centers of diversity) may be found far removed from the primary center of origin. These may be associated with domestication and human movement.

Determinations of centers:
1. Botanical evidence
2. Archeological evidence
3. Historical evidence
4. Linguistic evidence

(Items 2-4 most likely to determine center of domestication (secondary centers of origin))

Centers of Origin

Features:
- Geographical location of species origin
- Site of maximum adaptation
- Site of maximum diversity
- Presence of related species
- Usually associated with site of domestication
Centers of Origin – Major Crops
Lettuce – Europe and Asia
Cabbage – Europe
Beet – Europe
Carrot – Europe and Asia
Onion – Asia
Potato – South America
Sweet Potato – South America
Bean – South America

Pea – Europe and Asia
Tomato – Central America
Pepper – Central and South America
Cucumber – Asia and Africa
Cantaloupe – Asia
Watermelon – Africa
Squash – Central and North America
Sweet Corn – Mexico

Domestication
Changes in seed as a result of selection:
Size
Uniformity of germination
# of seeds per plant
Shattering
Dormancy
Hardness of seed coat

Domestication – Bean Example
<table>
<thead>
<tr>
<th>Trait</th>
<th>Wild</th>
<th>Domesticated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed dispersal</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Pod wall fibers</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Seed dormancy</td>
<td>70% germination</td>
<td>90% germination</td>
</tr>
<tr>
<td>Growth habit</td>
<td>Indeterminate</td>
<td>Determinate</td>
</tr>
<tr>
<td>Number of pods</td>
<td>43.2</td>
<td>7.5</td>
</tr>
<tr>
<td>Pod length</td>
<td>5.7 cm</td>
<td>9.3 cm</td>
</tr>
<tr>
<td>Seed weight (100)</td>
<td>3.5 g</td>
<td>19.5 g</td>
</tr>
<tr>
<td>Days to flower</td>
<td>69</td>
<td>46</td>
</tr>
<tr>
<td>Harvest index</td>
<td>0.42</td>
<td>0.62</td>
</tr>
<tr>
<td>Flower delay (16 hr)</td>
<td>&gt;90 days</td>
<td>0 days</td>
</tr>
</tbody>
</table>

Other morphological and physiological changes resulting from selection:
- Loss of survival traits
- Loss of photoperiod response (potato)
- Emergence of mutant types (brassica)
- Absence of toxic substances (tomato)
Domestication – Squash

Example of selected diversity in squash

Domestication – Tomato

Example of selected diversity in tomato

Domestication – Beans

Example of selected diversity in beans

Classification

Process of lumping numerous crop species into useful categories

Classification

Classified by:
Adaptation and hardiness

Classification

Classified by environmental adaptation:

<table>
<thead>
<tr>
<th>Warm-season (very tender)</th>
<th>Eggplant</th>
<th>Muskmelon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucumber</td>
<td>Lima bean</td>
<td>Okra</td>
</tr>
<tr>
<td>Muskmelon</td>
<td>Pepper</td>
<td>Pumpkin</td>
</tr>
<tr>
<td>Squash</td>
<td>Sweet potato</td>
<td>Watermelon</td>
</tr>
</tbody>
</table>

2/9/2018
Classification

Classified by environmental adaptation:

**Warm-season (tender)**
- Cowpea
- Sweet corn
- Tomato
- Snap bean
- Soy bean

**Cool-season (semi-hardy)**
- Beet
- Cauliflower
- Swiss chard
- Parsnip
- Carrot
- Celery
- Lettuce
- Potato

**Cool-season (hardy)**
- Cabbage
- Broccoli
- Brussels sprouts
- Cauliflower
- Onions
- Leeks
- Pea
- Radish
- Garlic
- Asparagus

Classification

Classified by life cycle:

**Annual**
- Cucumber, tomato, spinach, sweet corn

**Biennial**
- Beet, broccoli, carrot, onion, parsley

**Perennial**
- Asparagus, rhubarb, sweet potato

Classification

Classified by:

Adaptation and hardiness

Life Cycle

Classification

Classified by:

Parts used for food
**Classification**

**Classified by edible portion:**
- **Root** – beet, carrot, turnip
- **Bulb** – leek, onion, garlic
- **Stem** – asparagus, kohlrabi
- **Flower** – cauliflower, broccoli
- **Tuber** – potato

**Classification**

**Classified by edible portion:**
- **Fruit** – cucumber, tomato, squash
- **Leaf** – cabbage, lettuce, spinach
- **Petiole** – celery
- **Seed** – beans, pumpkin seed

**Classification**

**Classified by:**
- **Adaptation and hardness**
- **Life Cycle**
- **Parts used for food**
- **Taxonomic grouping**

**Botanical Classification**

- **Kingdom:** Plantae
- **Sub-Kingdom:** Land Plants (Embryophyta)
- **Division:** Seed Plants (Magnoliophyta)
- **Class:** Cone Bearing (Gymnospermae)
- **Subclass:** Monocotyledon (Liliopsida)
- **Dicotyledon (Magnoliopsida)**

**Plant Taxonomy**
Monocots

Corn - 1 seed leaf

Monocot - a plant whose embryo has one cotyledon

Dicots

Castor Bean 2 seed leaves

Vegetable Classification

Monocot vegetables:
Araceae – arum family
vegetables: taro, dasheen
related: calamus, jack-in-the-pulpit

Dioscoreaceae – yam family
vegetables: yam
related: wild yams

Vegetable Classification

Monocot vegetables:
Poaceae – grass family
vegetable: sweet corn
related: grasses, sedges

Amaryllidaceae – lily family
vegetables: onion, leek, garlic, shallot, chive, asparagus
related: lily, camas, solomon’s seal
Vegetable Classification

Dicot vegetables:
Polygonaceae – buckwheat family
vegetables: rhubarb, sorrel
related: knotweed, smart weed, dock

Dicot vegetables:
Amaranthaceae (Chenopodiaceae) – goosefoot family
vegetables: beet, swiss chard, spinach
related: lambsquarter, pigweed

Dicot vegetables:
Brassicaceae (Cruciferae) – mustard family
vegetables: cabbage, rutabaga, turnip, radish
related: wild mustards

Dicot vegetables:
Euphorbiaceae – spurge family
vegetables: cassava
related: poinsettia, castor bean, spurge

Dicot vegetables:
Fabaceae (Leguminosae) – pea family
vegetables: pea, bean, cowpea, soybean, peanut, others
related: alfalfa, acacia, lupine, clover

Dicot vegetables:
Malvaceae – mallow family
vegetables: okra
related: hibiscus, hollyhock
Vegetable Classification

Dicot vegetables:
Cucurbitaceae – gourd family
vegetables: watermelon, cantaloupe, squash, pumpkin, cucumber, others
related: luffa, wild cucumber

Dicot vegetables:
Apiaceae (Umbelliferae) – parsley family
vegetables: carrot, parsnip, parsley, celery, others
related: hemlock, cow parsnip

Dicot vegetables:
Convolvulaceae – morning glory family
vegetables: sweet potato
related: flowering morning glory, bindweed, dodder

Dicot vegetables:
Solanaceae – nightshade family
vegetables: potato, tomato, pepper, eggplant, others
related: nightshade, jimsonweed, physalis

Vegetable Classification

Dicot vegetables:
Asteraceae (Compositae) – composite (aster) family
vegetables: lettuce, chicory, endive, salsify, artichoke, others
related: dandelion, thistle, daisy, ragweed, sunflower

Botanical Classification

Additional Taxonomy (most useful) -
Family
Genus
Species
Cultivar
<table>
<thead>
<tr>
<th><strong>Botanical Classification</strong></th>
<th><strong>Botanical Classification</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Family:</strong></td>
<td><strong>Genus:</strong></td>
</tr>
<tr>
<td>An assemblage of genera that closely or uniformly resemble one another in general appearance and technical characters</td>
<td>Identifies a more or less closely related and definable group of plants that may include one or more species.</td>
</tr>
<tr>
<td></td>
<td>The species within a genus are usually structurally or phylogenetically related.</td>
</tr>
<tr>
<td><strong>Species:</strong></td>
<td><strong>Variety:</strong></td>
</tr>
<tr>
<td>A group of similar organisms capable of interbreeding and are distinctly different in morphological or other characteristics from other species in the same genus.</td>
<td>A subdivision of a species consisting of a population with morphological characteristics distinct from other species forms.</td>
</tr>
<tr>
<td></td>
<td>(considered a naturally occurring taxonomic division)</td>
</tr>
<tr>
<td><strong>Cultivar (cultivated variety):</strong></td>
<td><strong>Clone:</strong></td>
</tr>
<tr>
<td>Denotes certain cultivated plants that are alike in most important aspects of growth but are clearly distinguishable from others by one or more definite characteristics.</td>
<td>Identifies material derived from a single individual and maintained by vegetative propagation. (genetically identical)</td>
</tr>
<tr>
<td></td>
<td><strong>Line:</strong></td>
</tr>
<tr>
<td></td>
<td>A uniform sexually reproduced population, usually self-pollinated, that is seed propagated and maintained to the desired standard of uniformity by selection.</td>
</tr>
<tr>
<td></td>
<td>(genetically similar)</td>
</tr>
</tbody>
</table>
Botanical Classification

Strain:
A term used to identify plants of a given cultivar that possess similar characteristics but differ in some minor feature or quality

Botanical Classification

Additional Taxonomy -
Family
Genus
Species
Cultivar

Complete Latin Binomial includes the name of the individual who first described the species.

Botanical Classification

Family: Brassicaceae (Cruciferae)
Genus: Brassica
Species: oleracea
Group/Variety: capitata
Cultivar: ‘Golden Acre’
Strain: ‘Golden Acre YR’

Complete Latin Binomial - cabbage
Brassica oleracea L. var. capitata L. cv. Golden Acre YR
Commercially:
Brassica oleracea cv. Golden Acre YR

Growth and Development

Growth stages:
Germination
Establishment
Vegetative growth
Reproductive growth
Ripening and senescence
Growth and Development

Growth stages:

Germination - the beginning or resumption of growth by a spore, seed, bud, or other structure

Growth Stages

Germination

Process:
Water inbibition
Seed coat softening
Expansion of hypocotyl and root
Emergence

Characteristics:
Critical for plant productivity
Disease susceptibility
Requires near-ideal conditions

Establishment

Process:
Early shoot growth
Root elongation

Characteristics:
Environmental sensitivity
Determines future growth rate and potential

Vegetative Growth

Process:
Increase root mass and rooting depth
Rapid leaf area increase
Increase in stem and leaf mass
Large leaves and succulent growth produced
Factors Affecting Growth

Energy Production and Storage

Photosynthesis – CO₂ + H₂O → light → sugars (C₆H₁₂O₆)

↓

Transport

↓

Respiration (energy use), structural and chemical synthesis

Net photosynthesis = photosynthesis - respiration

Growth Stages

Vegetative Growth

Characteristics:
- Period of rapid cell growth and expansion
- High rate of photosynthesis
- Determines reproductive potential
- Heavy use of water and nutrients

Reproductive Growth

The transition from vegetative to reproductive growth is usually marked by flowering. Leaves receive environmental stimulus for the proper timing of flowering.

Reproductive Growth

Process:
- Organ differentiation
- Slowing or cessation of leaf expansion
- Flower production
- Fertilization and embryo growth
- Fruit growth
- Parallel storage organ growth in some species

Characteristics:
- Period of heavy fiber production
- Sensitivity for yield and quality
- Can be influenced by many factors including temperature, daylength, etc
**Growth Stages**

**Senescence**

The latter part of plant development which leads from maturity to the ultimate complete loss of organization and function.

**Process:**
- Cessation of new growth
- Loss of leaf area
- Increased susceptibility to opportunists
- Ripening of fruit and seed
- Plant death

**Characteristics:**
- Yield not influenced by external factors
- Usually not reversible
- Management inputs have little impact
- Critical period for fruit and seed quality

---

**Factors Affecting Growth**

**Light Factors**

- Intensity – most vegetable require full sun equivalent
- Duration – requirements vary by species, fruiting vegetables need more
- Wavelength – wavelengths 400-450, 650-700 best for photosynthesis

**Temperature**

- Optimum is the range for a crop that allows for maximum photosynthesis and normal respiration
- Optimum differs by species
- Optimum may change during growth period
- Diurnal fluctuations as important as average

- Temperatures above optimum slow growth and reduce quality (pungency, fibrousness)
  - rapid respiration, stomate closure, reduced photosynthesis
- Temperatures below optimum slow growth and affect quality by reducing sugar production and storage
  - reduce photosynthesis, transport, and respiration
Factors Affecting Growth

**Heat Units (Growing Degree Days, GDD)**
- Degree days above a crop baseline
- Average of daily high and low - baseline
  (onions 35, tomatoes 50, eggplants 60)
- Used for determining suitable environments and predicting harvest dates
- Doesn’t account for early soil temps, based on daily average not actual temps, doesn’t account for higher than optimum max temps

**Factors Affecting Growth**

**Water availability**
- Need constant water supply
  periodic stress reduces growth and quality
  stomate closure, reduction in cell division
- Soil moisture principles
  Water holding capacity
  Field capacity
  Optimum minimal soil moisture
  Permanent wilting point

**Factors Affecting Growth**

**Fertility**
- Require nutrients at or near optimum
  sub or supra-optimum impacts yield and may severely impact quality
- Seedlings need high levels of fertilizers
- Seasonal applications beneficial to long-season crops
- Can impact life expectancy, disease resistance, etc

**Factors Affecting Growth**

**Genetics and Physiology**
- Growth habit (determinate vs indeterminate)
- Vernalization requirement (or problem)
- Photoperiodism
  most crops are day neutral
- Tolerance to environmental stresses
**Factors Affecting Growth**

**Crop Management**

Many growth factors can be managed
Many stress and disease related problems can be ameliorated with proper management

---

**Vegetable Propagation**

**Types of propagules:**
- Botanical seed
- Transplants
- Vegetative cuttings, tubers, bulbs, rhizomes, roots, etc.
- Tissue culture

---

**Seed**

**What is a seed?**

Fertilized mature ovule including:
- Embryo (small undeveloped plant)
- Endosperm (food storage tissue)
- Seed coat (protective covering)

**Characteristics of good seed:**
- Genetically pure
- High germination
- High vigor
- No dormancy
- Disease free
- Free of weed seed and foreign matter

---

**Stand Establishment – Transplanting**

**Transplanting**

Plants are started in various kinds of plant growth structures and transplanted outdoors when conditions become favorable.
Extends growing season.
Stand Establishment – Transplanting

Methods for successful transplanting

- Frost protection
- Moisture control
- High level of fertility (e.g. 10-50-10 starter solution)
- Row covers – hot caps, cloches, plastic tunnels

Stand Establishment – Transplanting

Benefits

- Improve stand and production uniformity
- Force earliness
- Reduce seed costs
- Improve weed control
- Decrease season-long water use

Stand Establishment – Transplanting

Crops typically transplanted:

- Tomato
- Cauliflower
- Celery
- Broccoli
- Eggplant
- Cabbage
- Brussels sprouts
- Peppers
- Lettuce
- Melons
- Beets
- Onion (sets)
- Broccoli

Vegetative Propagation

Methods:

- Cuttings (sweet potatoes, taro, cassava)
- Tubers or bulbs (potatoes, onions, garlic)
- Root division (asparagus, rhubarb)

Soil Composition
## Soil Management

### Soil Types:

- **Organic**
  - Peat soils (>50% OM, partly decomposed)
  - Muck soils (<50% OM, mostly decomposed)

- **Mineral**
  - Sand (large particles, low WHC, low nutrients)
  - Silt (medium particles, high WHC, med nutrients)
  - Clay (small particles, med WHC, high nutrients)

### Soil Selection:

#### Organic soils
- Good for production of leaf, root, and bulb crops
- Good for germination of fine-seeded crops
- No crusting problems
- High fertility
- Slow to warm and prone to frost damage
- Poor drainage

#### Sands and Loamy Sands
- Preferred for early production
- Good for root and tuber crops
- Well drained and aerated
- Low nutrient content
- Very low WHC

#### Sandy Loams, Silt Loams, and Loams
- Preferred for most vegetable production
- Easy to work and give high yields
- Good WHC
- Moderate levels of natural nutrition
- Easy soils to maintain

#### Loamy Clays and Clays
- Suitable for late planted crops
- Productive in dryland production
- Good water retention during extended dry periods
- Poor aeration
- Can develop compaction or texture problems

### Soil organic matter
- Source of nitrogen, phosphorus, and sulfur
- Increases cation exchange
- Improves soil structure
- Improves porosity of heavy soils
- Improves heat absorption
Soil Management

Soil organic matter

Must be constantly renewed in mineral soils
Can have detrimental effects
High salt concentration
Layered soils
Nitrogen tie-up

Sources:
- Crop residues
- Animal manures decomposed fresh
- Green manures
- Cover crops

Soil Management

Soil pH

Optimum 5.0-7.0
Acid soils can be adjusted with lime
Alkaline soils are more difficult
Sulfur compounds for short-term adjustment
Addition of unavailable nutrients

Fertility - Mineral Nutrients

Macronutrients:
- Nitrogen
- Calcium
- Phosphorus
- Magnesium
- Potassium
- Sulfur
Fertility - Mineral Nutrients

Micronutrients:

(Fe) Iron (Cu) Copper
(Mn) Manganese (Zn) Zinc
Boron Cobalt
(Cl) Chlorine Molybdenum

Fertility - Mineral Nutrients

Fertilizer needs dependent on:

Crop
Soil type and pH
Residual nutrients
Organic matter

Fertility - Mineral Nutrients

Determination of fertilizer rates:

Determine intended crop
Collect soil samples
Follow published recommendations for soil type and location
Use tissue sampling and seasonal applications if appropriate

Irrigation

Amount and frequency dependent on:

Crop requirement
Environmental conditions
Soil type

Irrigation equipment type dependent on:

Intended crop use and crop response
Water availability and price
Soil characteristics

Table 8.2. Available soil water and infiltration rates in soils of various textures

<table>
<thead>
<tr>
<th>Soil texture*</th>
<th>Available soil water (in. / ft)</th>
<th>Infiltration rate (in. / hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse sand</td>
<td>0.4-0.7</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Fine sand</td>
<td>0.7-0.9</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>0.9-1.3</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>1.2-1.9</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Loam</td>
<td>1.8-2.6</td>
<td>0.3-0.5</td>
</tr>
<tr>
<td>Silt loam</td>
<td>2.0-3.0</td>
<td>0.3-0.5</td>
</tr>
<tr>
<td>Clay loam</td>
<td>2.6-3.0</td>
<td>0.1-0.3</td>
</tr>
<tr>
<td>Clay</td>
<td>1.8-2.4</td>
<td>0.1-0.3</td>
</tr>
</tbody>
</table>

*Soil textures are defined in Figure 2.2.
Weed Control

Common weeds in vegetables:

Grasses
- foxtail, wild oats, barnyard grass

Broadleaf
- redroot pigweed, lambsquarter, purslane, kochia, Canada thistle, bindweed

Sedges
- yellow nutsedge

Methods of weed control:

Cultivation
Mulching
- organic materials
- manmade materials
Herbicides

Disease Control

What is Plant Disease?

ANY malfunctioning of host cells and tissues that results from continuous irritation by a pathogenic agent or environmental factor and leads to the development of symptoms

Plant Pathogens:

Compete with crop plants by using metabolites, carbohydrates and other nutrients produced by the host
Reduce photosynthetic efficiency
Reduce water and nutrient uptake
Disrupt normal growth and metabolites at the cellular level

Disease Cycle – Pathogen Life Cycle

Stages of Disease Development:
- overwinter
- inoculation
- germination
- penetration
- infection
- incubation
- invasion
- reproduction
- dissemination

Disease-causing pathogens:

Viruses
Fungi
Bacteria
Mycoplasmae
**Disease-Causing Pathogens**

- **Fungi**
  - > 100,000 known species, most are saprophytic
  - Only 10,000 species are known to cause disease in plants

- **Beneficials**
  - Decay plant and animal tissues
  - Symbionts – mycorrhizae
  - Antibiotics – *Penicillium*, *Gleocadium* species

**Control of Fungal Diseases**

- Soil fumigation – methyl bromide, vapam
- Use disease free propagules
- Resistant varieties
- Fungicides
- Crop rotation
- Cultural practices – sanitation / no wounds
- Biocontrol agents / antagonists

**Virus Diseases**

- **Obligate parasites**
  - To cause disease, they must have a vector:
  - Insects (aphids, leafhoppers, thrips)
  - Soil-borne fungi
  - Nematodes
  - Infected seed
  - Mechanical transmission (humans)

**Control of Fungal Diseases**

- Virus Diseases
  - Given name based on host and symptoms:
    - Tomato Ringspot Virus
    - Cucumber Mosaic Virus
    - Tobacco Mosiac Virus
    - Potato Leaf Roll Virus

**Control of Bacterial Disease**

- Mostly copper based (Bordeaux mix, Kocide, copper sulfate)
- Antibiotics – streptomycin
- Resistant varieties
- Insect control
- Sanitation

**General Disease Control Strategies**

- **Disease control strategies:**
  - Utilize certified seed
  - Control refuge species
  - Select disease-free production sites
  - Use disease resistant cultivars
  - Utilize crop rotation
  - Optimize planting date for avoidance
  - Apply appropriate pesticides when necessary
  - Control vectors
Insect Control

Monitoring populations:
- Scouting
  - plant inspections for insects
  - plant inspections for injury
- Sweep nets
- Trapping
- Baits
- Hormone traps

Action decisions:
- Determine injury potential (life cycle)
- Determine economic threshold
- Determine potential for future population shifts (sources and reproductive rate)

Insect Control

Insect control strategies:
- Eliminate refuges
- Protect beneficial insects
- Understand the life cycle of important pests
- Design an effective scouting program
- Timely insecticide applications

Harvesting Goals

Harvest the crop from the garden or greenhouse at the correct maturity, with minimum damage and loss and as quickly as possible.

Maximum quality exists at the moment of harvest

Harvest Damage

Harvest and Handling Injury

Most vegetable losses result from harvest and handling damage:
- Blemishes resulting from bruising
- Increased respiration
- Moisture loss from damaged tissue
- Entrance wounds for pathogens
Handling Injury

Effect of drop height and picking stage:

Percent bruised fruit
- 0 in drop, green stage – 0%
- 12 in drop, green stage – 1.8%
- 0 in drop, breaker stage – 0%
- 12 in drop, breaker stage – 24.3%

Factors Affecting Quality

Factors that determine postharvest quality:
- Stage of crop maturity
- Harvest and handling injury
- Water loss
- Temperature during harvest, transport and storage
- Rate of respiration, ripening, and breakdown
- Infection with pathogenic organisms

Components of Harvesting

Maturity selection:
- Influences susceptibility to handling damage
- Ripening requirement (if any)
- Shelf-life
- Size
- Amount of cooling required

Crop Maturity

Basis for harvest timing decisions

Harvest index based on:
- Size
- Color
- Ability to withstand handling, storage, and transport
- Tendency for postharvest ripening

Crop Maturity

Examples of maturity index characteristics:
- Cantaloupe: fruit color and stem slip
- Tomato: fruit color
- Broccoli: head size and floral development
- Lettuce: head and/or leaf size
- Sweet corn: kernel color, kernel stanchiness

Crop Maturity

Some crops can be harvested at multiple stages of growth, but handling practices will be modified at each stage.

Tomato - green pick, pink stage, vine ripened
Squash – immature, mature
Potato – new potatoes, mature
Crop Maturity

Examples of maturity index characteristics:

Onion: drying and falling of tops
Potato: top death and skin-set
Carrot: length and diameter of root
Radish: size, time from planting
Cucumbers: size, color, firmness

Packing, Storing

The shelf life and period of effective storage of vegetables is determined by respiration and ripening.

Respiration: the process by which cells produce energy through oxidation of sugars and other energy-rich compounds

Ripening: irreversible softening and sweetening process by which vegetables become more edible

Temperature

Impact of improper temperatures:

Above optimum
- High rate of respiration and ripening
- High rate of water loss
- Rapid growth of decay organisms

Below optimum
- Frost injury
- Cold injury

Temperature

Optimum storage temps and shelf life:

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Temperature</th>
<th>Shelf Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broccoli</td>
<td>32°F</td>
<td>10-14 d</td>
</tr>
<tr>
<td>Cabbage</td>
<td>32</td>
<td>5-6 m</td>
</tr>
<tr>
<td>Cucumber</td>
<td>50</td>
<td>10-14 d</td>
</tr>
<tr>
<td>Okra</td>
<td>45</td>
<td>7-10 d</td>
</tr>
<tr>
<td>Squash</td>
<td>50</td>
<td>2-8 m</td>
</tr>
<tr>
<td>Sweet corn</td>
<td>32</td>
<td>5-8 d</td>
</tr>
<tr>
<td>Ginger</td>
<td>60</td>
<td>6 m</td>
</tr>
</tbody>
</table>
Water Loss

Effects of water loss:
- Quality reduction – shriveling and desiccation
- Excessive trim losses
- Loss of salable weight

Methods for reducing water loss:
- Harvest and handle in cool conditions
- Harvest well-watered crops
- Rapidly cool produce to proper storage temperatures
- Humidification if necessary

Water Loss

Optimum humidity level:
- Asparagus: 95-100%
- Beet: 98-100%
- Sweet corn: 95-98%
- Garlic: 60-70%
- Lettuce: 98-100%
- Watermelon: 90%
- Pepper (dry): 60%
- Pepper (bell): 90-95%

Packaging & Storage

Vegetable crops differ widely with respect to rates of respiration and ripening

Root Crops: low rates of respiration and small ripening changes
Leafy Crops: high rates of respiration and no or minor ripening changes
Immature Fruit Crops: high rates of respiration and incomplete ripening processes

Rates of Respiration

Sample of respiration rates:
- Very Low: peanut
- Low: potato, onion, sweet potato
- Moderate: tomato, lettuce, pepper
- High: green onions, snap beans
- Very High: broccoli, sweet corn
- Even Higher: peas, asparagus

Importance of respiration rate
- High respiration: rapid changes (decline) in quality
- Need for rapid handling and transport
- Short storage capabilities
- Short shelf life

Impact of temperature:
Respiration can be controlled by lowering temperature

For every 18 °F above optimum, the rate of deterioration doubles or triples (i.e. sweet corn at 50 °F (32 °C) has shelf life of 2-4 days (4-8 days))
Vegetables either can:

Produce ethylene:
cantaloupe, tomato, pepper
many tree fruits often shipped with vegetables

Or, be sensitive:
tomato, lettuce, cabbage, cauliflower, eggplant, okra, pepper, squash, watermelon

Ripening, Production of Ethylene

Ethylene Injury

Symptoms on Vegetables:
- Carrots – bitterness
- Cole Crops – turn yellow and limp
- Cucumbers – turn yellow and develop soft spots
- Asparagus – become fibrous and woody
- Lettuce – develop rust-spots
- Squash – turn yellow and develop soft spots

Rot & Breakdown

Rot in storage requires three things:
- Susceptible host (vegetable)
  All vegetable crops are prone to some disease
- Pathogenic organism
  Mostly fungal or bacterial
- Proper conditions or environment
  Temperature and humidity are critical

Rot & Breakdown

Conditions that increase incidence of rot
- Entry wounds and tissue damage
- High humidity
- High temperature
- Lack of adequate ventilation

Potato

Taxonomy

Dicotyledon
Family: Solanaceae
Genus and species: Solanum tuberosum L.
Related species: tomato, pepper, eggplant, tobacco, petunia, nightshade

Harvesting tubers at physiological maturity – note condition of vines
Curing & Wound Healing

- Potatoes need to be stored for approximately three to five weeks (in practice) at 50 to 60°F and ≥95% relative humidity
- Store in a well-ventilated space
- During this time, potatoes become more resistant to storage diseases and shrinkage
- Wound healing and suberization (formation of a protective layer between the tuber surface and the interior tissue) take place during this period
- Required for all potatoes regardless of storage time and intended use.

Asparagus

Taxonomy

Monocotyledon
Family: Amaryllidaceae (Asparagaceae)
Genus & species: *Asparagus officinalis*
Related species: wild onion, garlic, leek, members of the lily family

Washington Size Grades

Asparagus

Harvest periods

From seed:
- Year 1 – no harvest
- Year 2 (transplant) – no harvest
- Year 3 (transplant +1 yr) – 2 weeks harvest
- Year 4 – 3 weeks harvest
- Year 5 – 4 weeks harvest
- Year 6+ – 6-8 weeks harvest

Onion

Taxonomy

Monocotyledon
Family: Amaryllidaceae (Alliaceae)
Genus and species: *Allium cepa* L.
Related species: wild onion, garlic, leek, members of the lily family
Onion

Varieties

Bulbing
Spring-seeded types, fall-seeded types
Bulbing green types
Any bulbing variety harvested early
Non-bulbing types
A. fistulosum or hybrids, include related perennial species

Bolting (going to seed)

Induced by vernalization
Modified by genetic background, stage of development
Caused by daytime temperatures below 50 °F
Greater incidence of cool days increases bolting
Modified by age and size of plant
Older plants more prone to bolting

Harvest Preparation

Curing essential
Best under dry conditions, ambient temps (68 - 82 °F; field or ventilated storage)
Curing is complete when necks seal, scales dry
Topping is completed by hand or mechanically

Curing

Table 11 Effects of Curing on Storage Losses of Onions

<table>
<thead>
<tr>
<th>Method</th>
<th>Weight Loss (%)</th>
<th>Rot (%)</th>
<th>Weight Loss (%)</th>
<th>Rot (%)</th>
<th>Weight Loss (%)</th>
<th>Rot (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>31 days</td>
<td>63 days</td>
<td>87 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No curing</td>
<td>11.8</td>
<td>16.8</td>
<td>15.2</td>
<td>24.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial curing</td>
<td>6.3</td>
<td>11.2</td>
<td>14.0</td>
<td>28.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field curing</td>
<td>6.1</td>
<td>11.1</td>
<td>13.3</td>
<td>23.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at p = 0.05</td>
<td>3.3</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*All rot checked after first month.
NS = Not significant.
Source: Ref. 108.

Storage of bulb onions

Optimal at 32 degrees and 65-75% RH
Can be stored for 5-6 months (if free from rot problems)

Garlic

Taxonomy

Monocotyledon
Family: Amaryllidaceae (Alliaceae)
Genus and species: Allium sativum L.
Related species: onion, leek, ramps members of the lily family
Garlic

Taxonomy
Monocotyledon
Family: Poaceae (Graminae)
Genus and species: Zea mays L. var. saccharata Sturt.
Related species: field corn, teosinte, sorghum, wheat and other small grains, grasses

Sweet Corn

Harvest
Harvest indices
Dried silks
Tight husk appearance
Kernels nearing full color, firm
Processing indices
% solids, % alcohol insoluble solids, % WSP, pericarp test, trimetric test (moisture, pericarp, size)

Prediction of Harvest Date
Three methods used:
1. Physiological development
2. Published “Days to harvest”
3. Corn heat units

Handling and Storage
Hydrocooled or room cooled to <50 degrees
Handled and shipped at 32 degrees, 90-95% RH
Rapid conversion of sugars to starch
Storage, shipping, shelf life – 6-8 days
Sweet Corn

Tomato

Taxonomy

Dicotyledon  
Family: Solanaceae
Genus & species: *Solanum lycopersicum* L.
Related species: potato, chili pepper, eggplant, tobacco, petunia, tomatillo, cape gooseberries, nightshade

Fruits maturation

Fruit ripen 35-60 after anthesis
Color influenced by light and temperature
Optimum 70-85 degrees (no color >100)
Light accelerates and increases intensity
Accompanied by changes in composition

Storage

Storage practices dependent on stage of ripening
Mature green
Susceptible to chilling injury
Held 55-65 degrees, 85% RH, 2-3 weeks
Ripening complete at 65-70 degrees
Fully red
45–50 degrees, 90% RH, 4-6 days
Lettuce

Taxonomy

Dicotyledon
Family: Asteraceae
Genus & species: Lactuca sativa L.
Related species: Sunflower, artichoke, sunchoke, dandelion, salsify, endive

Production - Harvest

Harvest indices
Head of adequate size
Head firm
Leaves green
No bolting

Cole Crops

Production – Harvest

Each crop has specific harvest indices
Harvest interval varies widely with crop
Most are hand harvested (machine assisted)
Immediate cooling usually required
Field trimming and/or packing is common

Handling and Storage

Cooled w/ water, ice or room-cooled
Commonly stored at 32 degrees, 98-100% RH
Storage life varies by crop
CA storage effective for some crops
Ethylene causes senescence and injury

Cabbage

Broccoli
Broccoli
Broccoli - overmature

Cauliflower

Brussels Sprouts

Kohlrabi

Kale - Redbor

Chinese Cabbage – Pe-tsai Type
**Carrot**

**Taxonomy**

- Dicotyledon
- Family: Apiaceae
- Genus & species: *Daucus carota* L. var. *sativa*
- Related species: celery, parsnip, parsley, hemlock, fennel, dill, cumin

**Production - Harvest**

- Timing determined by end use
- Harvest 2 ways:
  - With tops (bunch carrots)
  - Without tops (bulk carrots)
- Bruise prevention important if stored

**Storage**

- Optimal at 32 °F and 95% RH
- Stored best with tops removed
- Can be stored for 7-9 months (WHY?)

---

**Beet**

**Taxonomy**

- Dicotyledon
- Family: Amaranthaceae
- Sub-family: Betoideae
- Genus & species: *Beta vulgaris* L. var. *vulgaris*
- Related species: spinach, Swiss chard, lambs-quarter, sugar beet

**Storage**

- Store at 35 degrees F, 90% RH
- Storage life:
  - Bunched beets - 10-15 days (WHY?)
  - Topped beets - 8 months

---

**Watermelon**

**Taxonomy**

- Dicotyledon
- Family: Cucurbitaceae
- Genus and species: *Citrullus lanatus* (Thunb.) Matsum. & Nakai
- Related species: melons, gourds, luffa, cucumber
Melon

Taxonomy

Dicotyledon
Family: Cucurbitaceae
Genus and species: Cucumis melo L.
Related species: watermelon, gourds, luffa, cucumber

Production – Harvest and handling

Must be harvested fully ripe

Harvest indices

Muskmelon
  Full slip
  Yellow ground color

Winter melons
  Slightly spongy stem end
  Yellow or gold ground color