Asotin Master Gardener Training
Growing Vegetables

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Gary Larson
"Early vegetarians returning from the kill"

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 - definition

Are Not:
- Cereal crops
- Sugar crops
- Pulse crops*
- Woody fruit crops

Are:
- Almost everything else
- 90+ economically important crops of various types and species

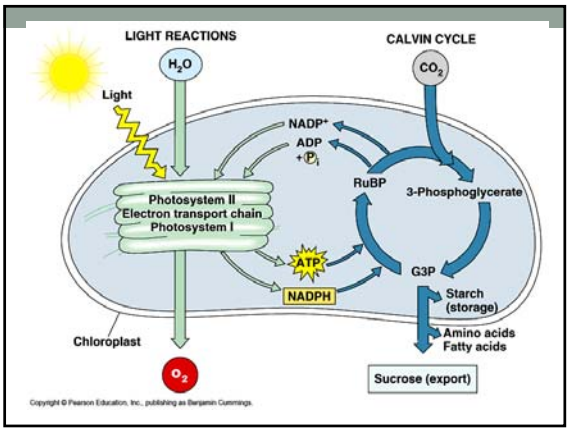
Vegetables – other features

- 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

Nutrition

- **Two Important Nutritional Facts:**

1) All foods come directly or indirectly from plants.



Nutrition

- **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.

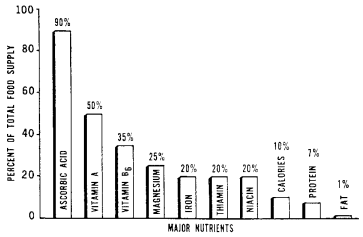


FIGURE 1 Nutritional contribution of fruits and vegetables compared to percentage of total food supply. (From Ref. 5.)

Nutrition

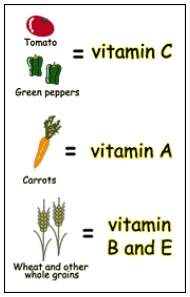
- **Macronutrients:**

carbohydrates
fats
essential fatty acids
proteins

Nutrition

- **Micronutrients:**

essential vitamins
mineral elements



Nutrition

- **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 cucurbits

Nutrition – Vital Crops

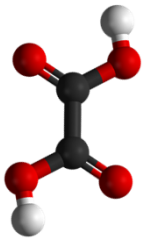
- **Protein**
  - beans
  - peas
  - sweet corn
  - leafy crucifers
  - potato
- **Pro-Vitamin A**
  - carrot
  - squash
  - squash
  - green leafy vegetables
  - pepper
  - green peas, beans
  - orange/yellow flesh sweet potato

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

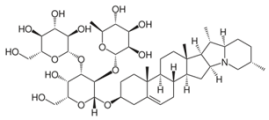
Plant Families with Toxicants

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



Plant Families with Toxicants

- Poaceae – bamboo – cyanogenic glucoside (decreases with boiling)
- Polygonaceae – rhubarb – oxalic acid, glucoside, and leaf tissue poison
- Solanaceae – potatoes and tomatoes - alkaloids and protease inhibitors; peppers - capsaicin



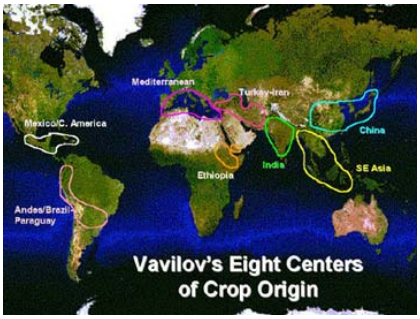
Origin, Evolution

- **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=WQz5lb72XbE

Origin, Evolution

- **Nikolai Ivanovich Vavilov**

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

Centers of Origin

Determination 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

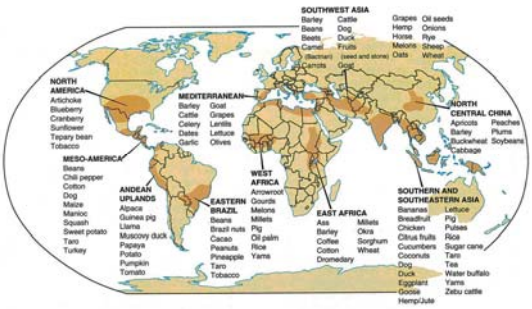
Site of maximum adaptation

Site of maximum diversity

Presence of related species

Usually associated with site of domestication

Centers of Origin



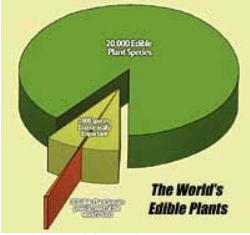
Centers of Origin – Major Crops

Lettuce – Europe and Asia
Cabbage – Europe
Beet – Europe
Carrot – Europe and Asia
Onion – Asia
Potato – South America
Sweet Potato – South America
Bean – South America

Centers of Origin – Major Crops

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

Edible species
20,000



Species used for food
3,000

Species cultivated
200

Major crop species - 25

Domestication

Changes in seed as a result of selection:

Size ↑
Uniformity of germination ↑
# of seeds per plant ↓
Shattering ↓
Dormancy ↓
Hardness of seed coat ↓

Domestication

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 – Bean Example

Trait	Wild	Domesticated
Seed dispersal	Present	Absent
Pod wall fibers	Present	Absent
Seed dormancy	70% germination	90% germination
Growth habit	Indeterminate	Determinate
Number of pods	43.2	7.5
Pod length	5.7 cm	9.3 cm
Seed weight (100)	3.5 g	19.5 g
Days to flower	69	46
Harvest index	0.42	0.62
Flower delay (16 hr)	>60 days	0 days

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:

Warm-season (very tender)

Cucumber	Eggplant
Lima bean	Muskmelon
Okra	Pepper
Pumpkin	Squash
Sweet potato	Watermelon

Classification

Classified by environmental adaptation:

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

Classification

Classified by environmental adaptation:

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

Classification

Classified by environmental adaptation:

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

Classification

Classified by:

Adaptation and hardiness

Life Cycle

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

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 hardiness

Life Cycle

Parts used for food

Taxonomic grouping

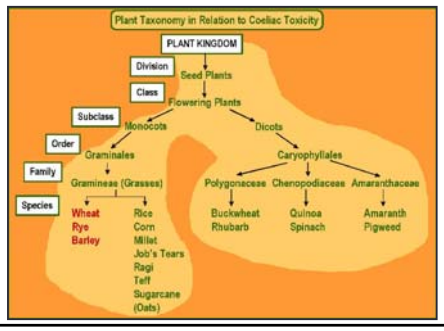
Classification

Linnaeus 1735	Haeckel 1866	Chatton 1925	Copeland 1938	Whittaker 1969	Woese 1990	Cavalier-Smith 1998
2 kingdoms	3 kingdoms	2 empires	4 kingdoms	5 kingdoms	3 domains	6 kingdoms
(not treated)	Protista	Prokaryota	Monera	Monera	Bacteria Archaea	Bacteria
			Protoctista	Protista		Protozoa Chromista
Vegetabilia	Plantae	Eukaryota	Plantae	Plantae Fungi	Eucarya	Plantae Fungi
Animalia	Animalia		Animalia	Animalia		Animalia

Botanical Classification

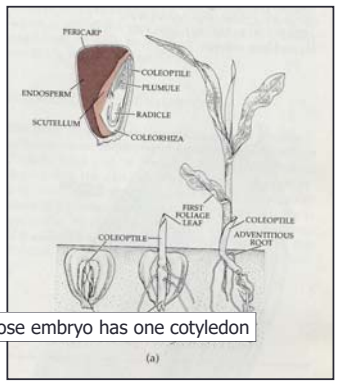
Kingdom:	Plantae
Sub-Kingdom:	Land Plants (Embryophyta)
Division:	Seed Plants (Magnoliophyta)
Class:	Cone Bearing (Gymnospermae) Flowering (Angiospermae)
Subclass:	Monocotyledon (Liliopsida) Dicotyledon (Magnoliopsida)

Plant Taxonomy



Monocots

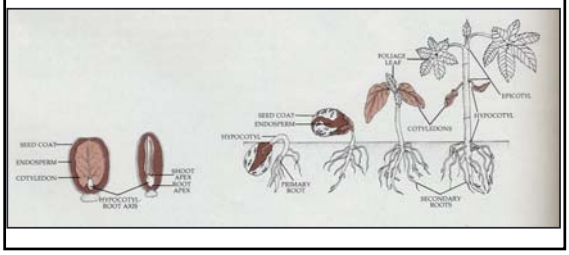
Corn - 1 seed leaf



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

Vegetable Classification

Monocot vegetables:

Dioscoreaceae – yam family

vegetables: yam

related: wild yams

Vegetable Classification

Monocot vegetables:

Poaceae – grass family

vegetable: sweet corn

related: grasses, sedges

Vegetable Classification

Monocot vegetables:

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

Vegetable Classification

Dicot vegetables:

Amaranthaceae (Chenopodiaceae) – goosefoot family

vegetables: beet, swiss chard, spinach

related: lambsquarter, pigweed

Vegetable Classification

Dicot vegetables:

Brassicaceae (Cruciferae) – mustard family

vegetables: cabbage, rutabaga, turnip, radish

related: wild mustards

Vegetable Classification

Dicot vegetables:

Euphorbiaceae – spurge family

vegetables: cassava

related: poinsettia, castor bean, spurge

Vegetable Classification

Dicot vegetables:

Fabaceae (Leguminosae) – pea family

vegetables: pea, bean, cowpea, soybean, peanut, others

related: alfalfa, acacia, lupine, clover

Vegetable Classification

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

Vegetable Classification

Dicot vegetables:

Apiaceae (Umbelliferae) – parsley family

vegetables: carrot, parsnip, parsley, celery, others

related: hemlock, cow parsnip

Vegetable Classification

Dicot vegetables:

Convolvulaceae – morning glory family

vegetables: sweet potato

related: flowering morning glory, bindweed, dodder

Vegetable Classification

Dicot vegetables:

Solanaceae – nightshade family

vegetables: potato, tomato, pepper, eggplant, others

related: nightshade, jimson-weed, 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

Botanical Classification

Family:

An assemblage of genera that closely or uniformly resemble one another in general appearance and technical characters

Botanical Classification

Genus:

Identifies a more or less closely related and definable group of plants that may include one or more species.

The species within a genus are usually structurally or phylogenetically related.

Botanical Classification

Species:

A group of similar organisms capable of interbreeding and are distinctly different in morphological or other characteristics from other species in the same genus.

Botanical Classification

Variety:

A subdivision of a species consisting of a population with morphological characteristics distinct from other species forms.

(considered a naturally occurring taxonomic division)

Botanical Classification

Cultivar (**cult**ivated **var**iety):

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.

Botanical Classification

Clone:

Identifies material derived from a single individual and maintained by vegetative propagation. (genetically identical)

Line:

A uniform sexually reproduced population, usually self-pollinated, that is seed propagated and maintained to the desired standard of uniformity by selection. (genetically similar)

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.

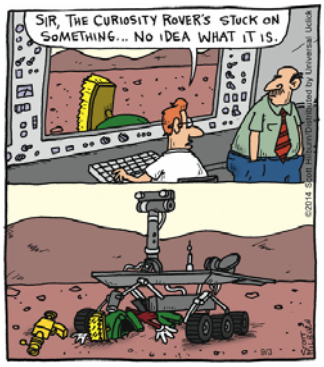
Botanical Classification

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

Botanical Classification



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

Growth Stages

Germination

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

Growth Stages

Establishment

Process:
- Early shoot growth
- Root elongation

Growth Stages

Establishment

Characteristics:
- Environmental sensitivity
- Determines future growth rate and potential

Growth Stages

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 – $CO_2 + H_2O \rightarrow$ light $\rightarrow$ sugars ($C_6H_{12}O_6$)

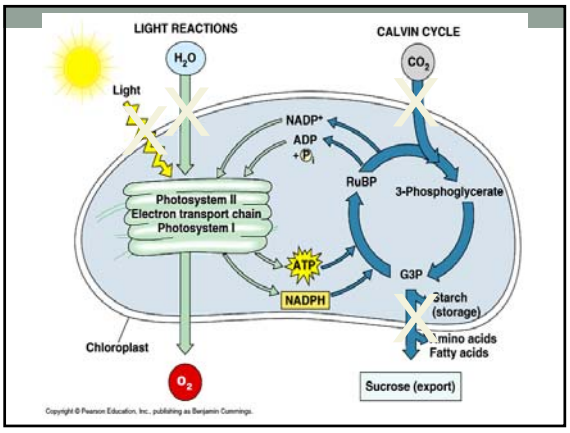
↓

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

Growth Stages

Reproductive Growth

The transition from vegetative to reproductive growth is usually marked by flowering.

Leaves receive environmental stimulus for the proper timing of flowering.

Growth Stages

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

Growth Stages

Reproductive Growth

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.

Growth Stages

Senescence

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

Growth Stages

Senescence

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

Factors Affecting Growth

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

Factors Affecting Growth

Temperature

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

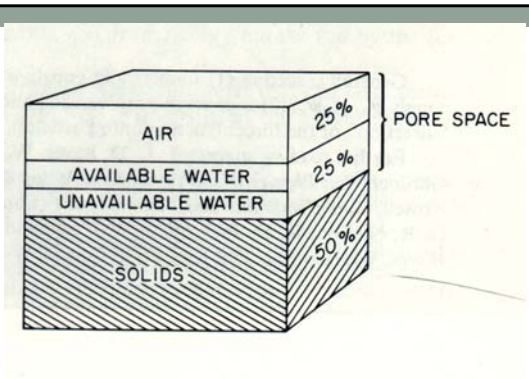
Doesn't account for early soil temps, based on daily average not actual temps, doesn't account for higher than optimum max temps

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



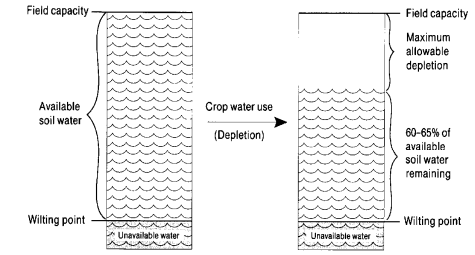


Fig. 8.2. Available soil water is the difference between the field capacity of a soil (the amount of water retained in the total soil pore space after saturated soil has drained) and the permanent wilting point (the point at which plants can no longer obtain water from the soil and thus wilt and die). Allowable depletion is the point to which available soil water can be depleted without inducing plant stress. For potatoes, the soil must always be maintained above 60–65% of available soil water.

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.

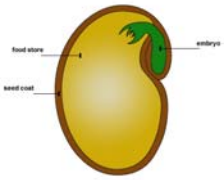
Tissue culture

Seed

What is a seed?

Fertilized mature ovule including:

- Embryo (small undeveloped plant)
- Endosperm (food storage tissue)
- Seed coat (protective covering)



Seed

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

Use of plugs

Use of vigorous plants

Appropriate hardening (7-14 days)

High level of fertility (e.g. 10-50-10 starter solution)

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

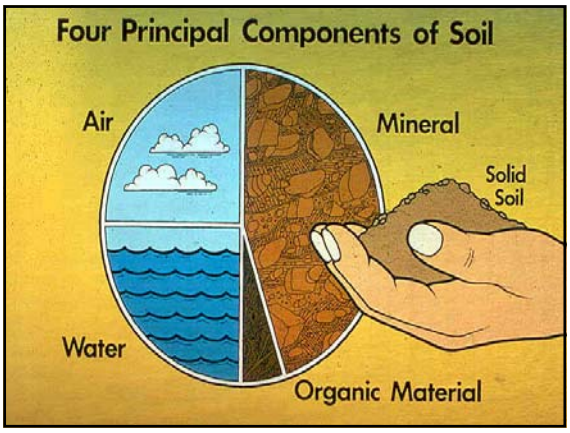
Vegetative Propagation

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 Management

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

Soil Management

Soil Selection:

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

Soil Management

Soil Selection:

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

Soil Management

Soil Selection:

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 Management

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

Soil Management

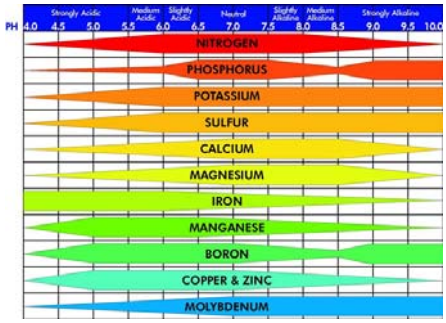
Soil organic matter

Sources:

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

Soil Management

Soil Management



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	**C**alcium
Phosphorus	**M**agnesium
(**K**) Potassium	**S**ulfur

Fertility - Mineral Nutrients

Micronutrients:

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

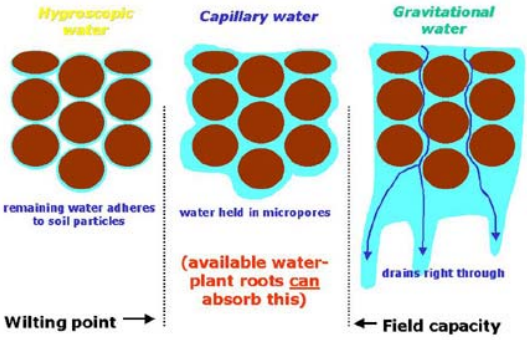
Soil type

Irrigation equipment type dependent on:

Intended crop use and crop response

Water availability and price

Soil characteristics



Irrigation

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

Soil texture[a]	Available soil water (in./ft)	Infiltration rate (in./hr)
Coarse sand	0.4–0.7	0.5–1.0
Fine sand	0.7–0.9	0.5–1.0
Loamy sand	0.9–1.3	0.5–1.0
Sandy loam	1.2–1.9	0.5–1.0
Loam	1.8–2.6	0.3–0.5
Silt loam	2.0–3.0	0.3–0.5
Clay loam	2.0–2.6	0.1–0.3
Clay	1.8–2.4	0.1–0.3

[a]Soil textures are defined in Figure 2.3.

Weed Control

Common weeds in vegetables:

Grasses
foxtail, wild oats, barnyard grass

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

Sedges
yellow nutsedge

Weed Control

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

Disease Control

Plant Pathogens:

Compete with crop plants by using metabolites, carbohydrates and other nutrients produced by the host

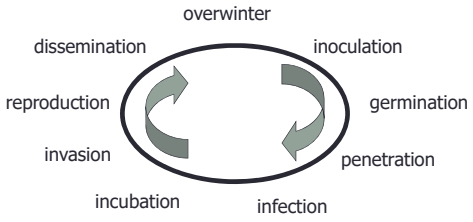
Reduce photosynthetic efficiency

Reduce water and nutrient uptake

Disrupt normal growth and metabolites at the cellular level

Disease Cycle – Pathogen Life Cycle

Stages of Disease Development



Disease Control

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*, *Gleocladium* 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)

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

Insect Control

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:

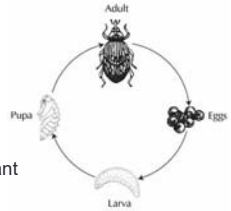
Eliminate refuges

Protect beneficial insects

Understand the life cycle of important pests

Design an effective scouting program

Timely insecticide applications

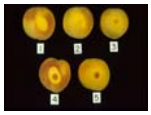


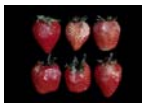
Harvesting Goals

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

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:

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 starchiness





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:

Broccoli	32ºF	10-14 d
Cabbage	32	5-6 m
Cucumber	50	10-14 d
Okra	45	7-10 d
Squash	50	2-8 m
Sweet corn	32	5-8 d
Ginger	60	6 m

Water Loss

Effects of water loss:

Quality reduction – shriveling and desiccation

Excessive trim losses

Loss of salable weight

Water Loss

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%

Packing & 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

Rates of Respiration, Ripening

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 °F) has shelf life of 2-4 days (4-8 days)

Ripening, Production of Ethylene

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

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

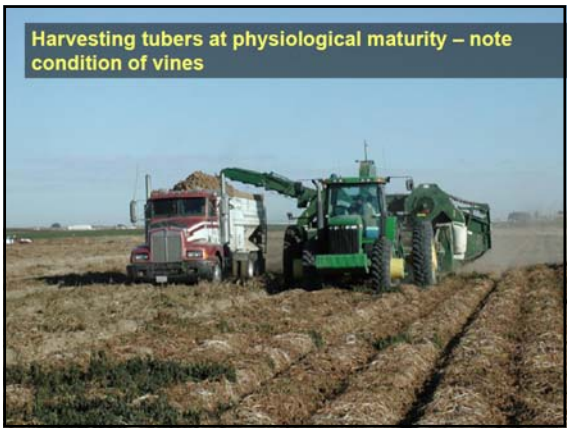
Potato

Taxonomy

Dicotyledon
Family: Solanaceae

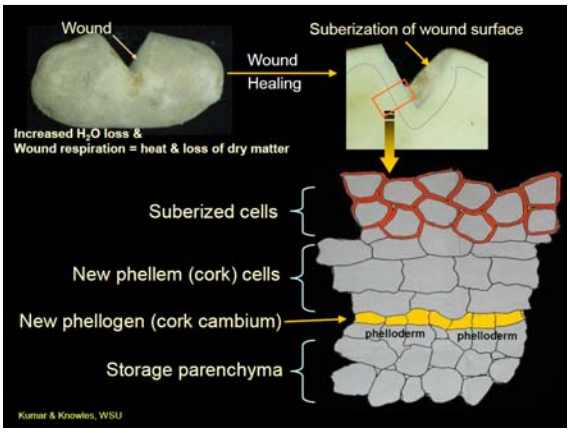
Genus and species: *Solanum tuberosum* L.

Related species: tomato, pepper, eggplant, tobacco, petunia, nightshade



Curing & Wound Healing

- Potatoes need to be stored for approximately three to five weeks (in practice) at 50 to 60ºF 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

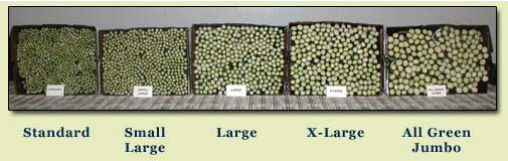
Taxonomy

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

Onion

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

Onion

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

Onion

Curing

Table 11 Effects of Curing on Storage Losses of Onions

Method	31 days Weight loss	31 days Rot (%)	63 days Weight loss	63 days Rot (%)	87 days Weight loss	87 days Rot (%)
No curing	11.8	76.7	a	a	a	a
Artificial curing	6.3	12.3	10.8	16.3	13.2	24.8
Field curing	6.1	20.0	11.2	23.3	14.5	36.5
LSD at $p = 0.05$	3.3	14.9	NS	NS	NS	NS

[a]All rotted after first month.
NS = Not significant.
Source: Ref. 108.

Onion

Storage of bulb onions

Optimal at 32 degrees and 65-75% RH

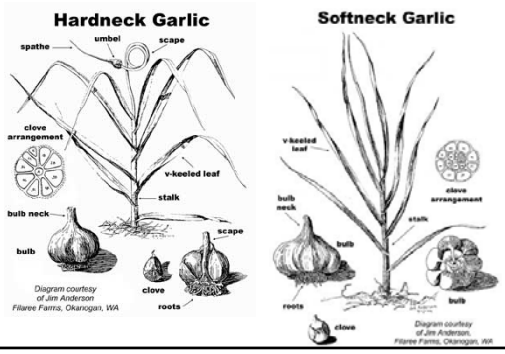
Can be stored for 5-6 months (if free from rot problems)

Garlic

Taxonomy

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

Garlic



Sweet Corn

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)

Sweet Corn

Prediction of Harvest Date

Three methods used:
1. Physiological development
2. Published "Days to harvest"
3. Corn heat units

Sweet Corn

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

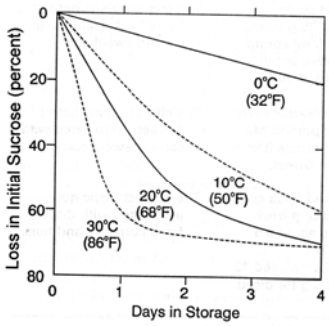


FIGURE 9 Sucrose depletion in sweet corn at four temperatures.

Sweet Corn

Sweet Corn

Tomato

Taxonomy

Dicotyledon

Family: Solanaceae

Genus & species: *Solanum lycopersicum* L.

Related species: Potato, chili pepper, eggplant, tobacco, petunia, tomatillo, cape gooseberries, nightshade

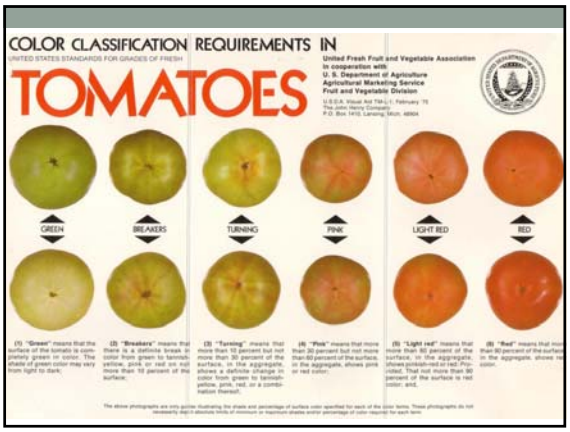
Tomato

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



Tomato

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

Lettuce

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

Cole Crops

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

Carrot

Production - Harvest

Timing determined by end use

Harvest 2 ways:

With tops (bunch carrots)

Without tops (bulk carrots)

Bruise prevention important if stored

Carrot

Storage

Optimal at 32 ºF 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

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

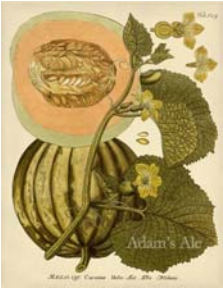
Melon

Taxonomy

Dicotyledon
Family: Cucurbitaceae

Genus and species:
Cucumis melo L.

Related species:
watermelon, gourds, luffa, cucumber



Melon

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