COTTON PLANT

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Cotton Plant ?

- Cotton is a major agricultural and industrial crop in more than 60 countries
- With its production, processing and marketing cotton provides
    - Employment
    - Income

for hundreds of millions of people.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Cotton Plant ?

Cotton is unique among agricultural crops,

- provides
  - food
  - fiber.

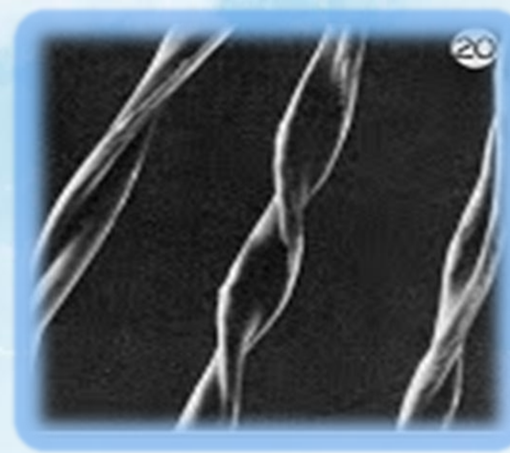
Cotton is a major fiber crop,

- provides
  - an edible oil
  - seed
  - by-products for livestock food.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Cotton Plant ?

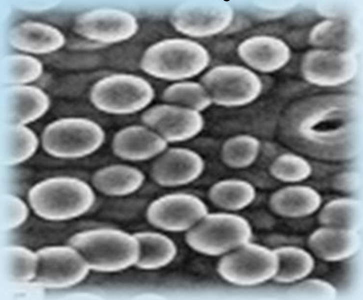
- However most of the research on cotton and the treatment it receives in the World are limited to its recognition as a fiber crop.
- Cottonseed accounts for two-thirds of the weight of harvest, but all-out efforts are made to improve primarily the fiber produced.

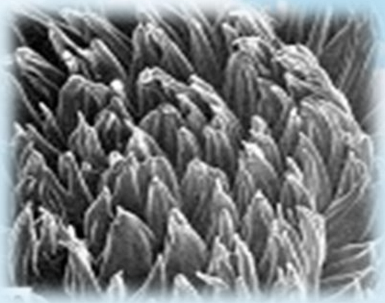


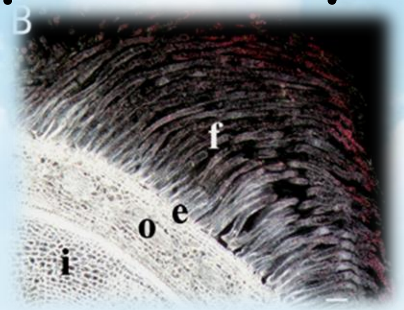
Poehlman and Sleper (1995); Kim and Triplet (2001); Chaudry and Guitchounts (2003); Kulkarni et al (2009)

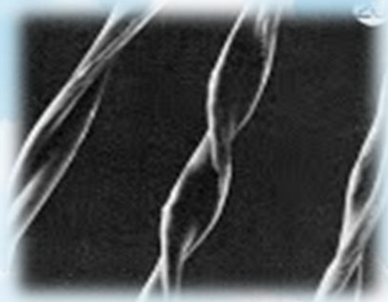
Cotton Plant ?

- Natural cotton fiber is a great gift from nature.
- It is unique among plant fibers in that each is a single cell.
- Cotton is mainly cultivated for the production of those elongated single-celled fibers valued worldwide too much and which sustain one of the world's largest industries.
- In addition to being the world's most important textile fiber crop, cotton is the world's second-most important oilseed crop after soybean.









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;http://www.eeob.iastate.edu/faculty/WendelJ/geneexpression.htm; Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

History ?

- Cotton *(Gossypium spp.)* has been cultivated in tropical and subtropical climates of the world since prehistoric times.
- Although the wild cotton species are often woody perennials, ranging from shrubs to trees, the domesticated cottons are generally cultivated as herbaceous row crops, or, in a few areas of the world, by ratooning as with the Moco cottons of Brazil.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Taxonomy

- Cotton is a member of the
  - order Malvales,
  - family Malvaceae
- This makes it a relative of such familiar plants as Okra, Jute, mallow, Ornamental Hibiscus and etc.








http://www.malvaceae.info/Genera/Hibiscus/galleryL.html

Taxonomy

COTTON'S FAMILY TREE	
Rank	Main line of descent
Order	Malvales
Family	Malvaceae
Tribe	Gossypieae
Genus	Gossypium

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Taxonomy

- Gossypium plants are small trees, shrubs or sub shrubs that grow in tropical and sub-tropical regions of Africa, Asia, Australia and America.
- The genus Gossypium consist of 50 wild and cultivated species .
- Forty five of the species are diploid, having a 2n chromosome number equal to 26.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Taxonomy

- Only four species of Gossypium are grown on a commercial scale in the World.

<u>New World species</u>	<u>Origin</u>
• G. hirsutum L., →	Mexico
• G. barbadense L. →	Peru

<u>Old World or Asiatic cottons</u>	<u>Origin</u>
• G. arboreum L. →	Indo-Pak sub-continent
• G. herbaceum L. →	Southern Africa

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Taxonomy

- The origin of these four species, cultivated in four different areas of the World so far apart, indicates that they were domesticated independently of each other.
- G. barbadense is the most photoperiodic (sensitive to day lenght) species among the four cultivated species, which limits its cultivation to only a few countries.
- The most commonly cultivated species of cotton in the World is G. hirsutum L. This and G. barbadense are the most important agricultural cottons.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Taxonomy

- Both are allotetraploids (AADD genomes) of New World origin and presumably result from an ancient cross between an Old World A genome and a New World D genome.
- Euploids (exact multiplication of haploid chromosome number) of these plants have 52 somatic chromosomes, and frequently desinated as AADD.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Taxonomy

- Three additional New World allotetraploids occur in the genus,
- G. tomentosum from Hawaii,
- G. mustelinum from northeast Brazil and
- G. darwinii from Galapagos Islands.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Taxonomy

Acala Cotton

- The Acala type is an upland cotton (*G.hirsutum*) originally selected from germplasm introduced from Mexico to USA.

Egyptian Cotton

- Egyptian Cotton belongs to *G. barbadense* and originated from crosses between Peruvian cotton and Sea Island cotton.

Sea Island Cotton

- Sea Island Cotton also belongs to the *G. barbadense* species and has the best fiber quality in the World. Sea Island cotton originated in the West Indies and Sea Islands of the southeast coast of the USA.

Taxonomy

Pima Cotton

- Pima was developed from crosses between Sea Island and Egyptian cotton.

Tangüis Cotton

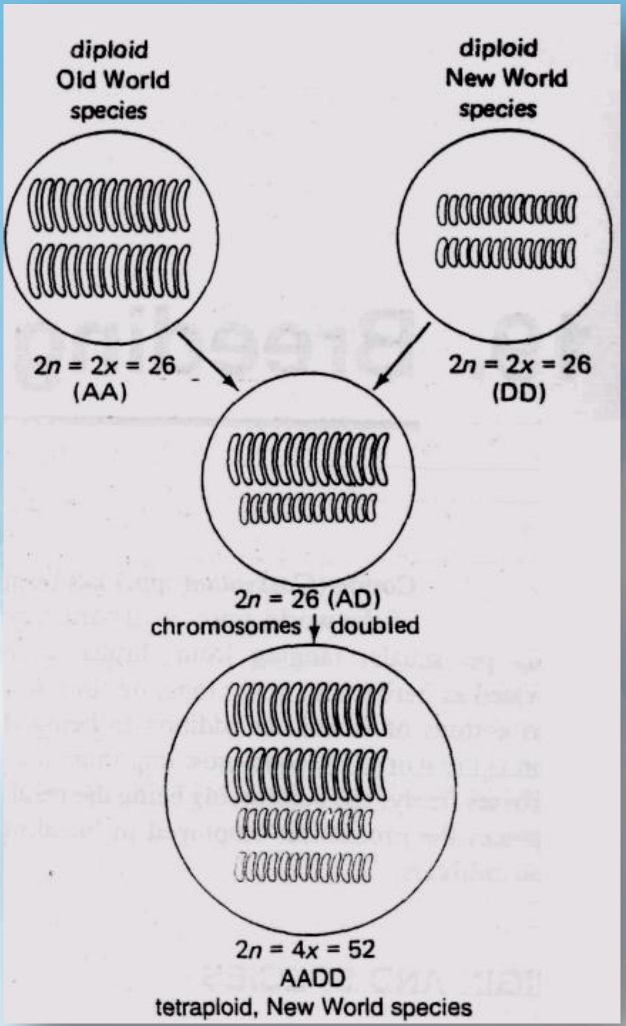
- It is a kind of *G. barbadense* cotton grown in Peru that was derived from a cross between sporadic village cotton of Indian tribes and an upland variety

Taxonomy

Genetic Origin of the Tetraploid Cotton

The tetraploid New World cottons ($2n = 4x = 52$, genomes AADD) are allotetraploids, in which the AA genomes of the diploid, Old World (Asiatic) species are combined with the DD genomes of diploid, New World (American) species.

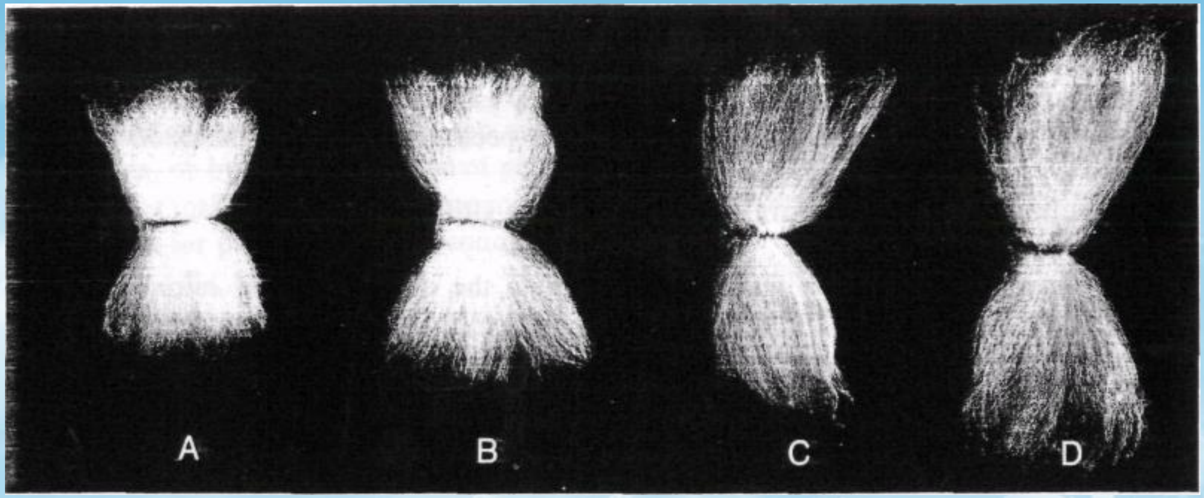
The chromosomes of the AA genomes are larger than the chromosomes of the DD genomes.



Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Taxonomy

Comparison of Stable Lenght in Cotton



(A) A short- to medium-staple storm-proof Plains type.

(B) A medium- to long-staple Acala type.

(C) An extra-long-staple Pima type.

(D) Extra-long staple of Sea Island, a type no longer grown in the United States.

A and B are G. hirsutum; C and D are G. barbadense.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Morphology and Anatomy

- The cotton plant
- is a perennial
- has an indeterminate growth habit
- is reputed to have the most complex structure of any major field crop.
- Its indeterminate growth habit and sympodial fruiting branches result in a four-dimensional occupation of space and time that is difficult to analyze.

Oosterhuis and Jernstedt (1999)

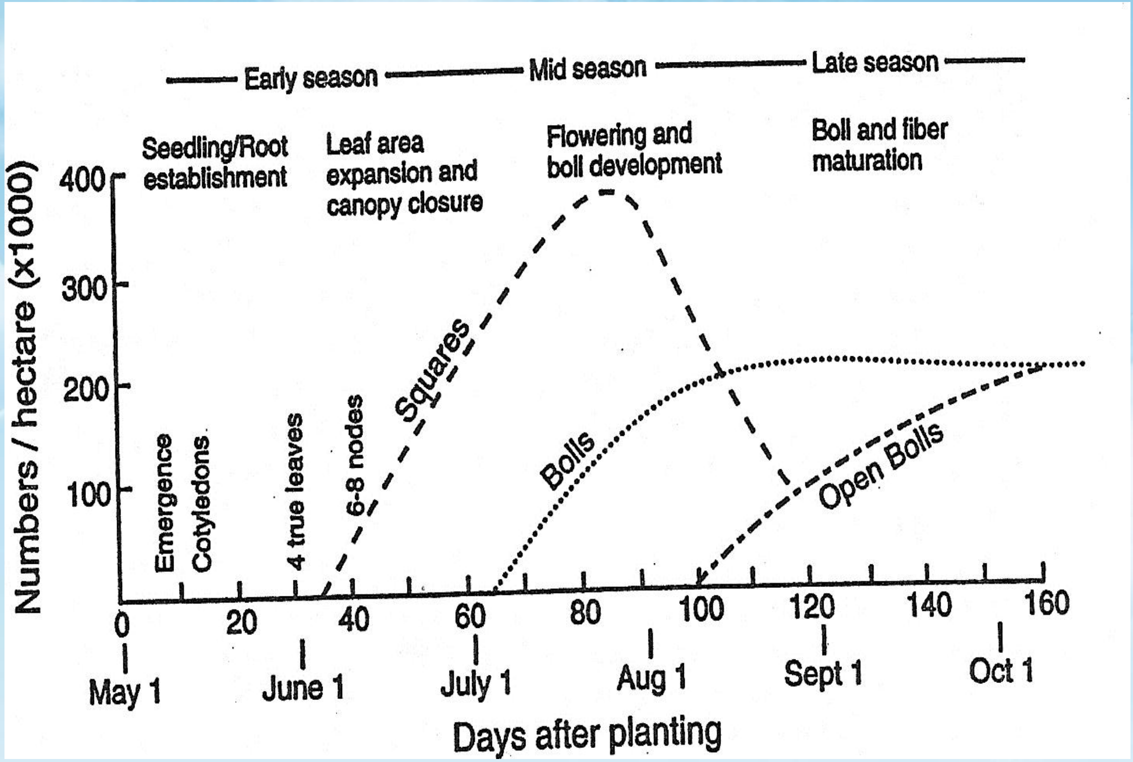
Morphology and Anatomy

- Furthermore, these characteristics ensure that vegetative and reproductive growth are occurring simultaneously.
- Thereby increasing the difficulty of efficiently managing production practices.
- Associated with this complex growth habit is an extreme sensitivity to adverse environmental conditions, reflected in excess fruit abscission.
- An understanding of cotton growth and development in commercial production is important in the continuing efforts of growers to produce lint and seed more efficiently and profitably.

Oosterhuis and Jernstedt (1999)

Morphology and Anatomy

- Plant development in cotton proceeds through a number of stages, which for practical management reasons maybe divided into four main growth stages



1. germination and seedling establishment,
2. leaf area and canopy development,
3. flowering and boll development, and
4. maturation

Landivar and Benedict (1996);Oosterhuis and Jernstedt (1999)

Morphology and Anatomy

- Each stage involves the elaboration of new morphology and anatomy that builds upon the scaffolding and structures preceding it.
- Each elaboration is a product of genetics and environment.
- However, transitions between these successive stages are subtle and not always clearly distinguishable.
- Furthermore, each stage may have different physiological processes operating with specific requirements.

Landivar and Benedict (1996);Oosterhuis and Jernstedt (1999)

Morphology and Anatomy

- If growers are aware of these stage-dependent differences and requirements in cotton growth, then many problems in crop management may be avoided, potentially resulting in increased yields and profits.
- To understand each of these stages it is needed to have a knowledge of the morphology and anatomy of the cotton plant and crop physiology.

Landivar and Benedict (1996);Oosterhuis and Jernstedt (1999)

Root

- The cotton plant has a tap root system. The root has the primary function of absorbing and transporting water and nutrients from the soil to the plant parts and anchoring the plant.
- The radical forms the primary root that grows downward into the soil.

Eksi (2004); Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Root

- The size of the root depends on the physical texture of the soil, soil fertility, soil temperature and the amount of water in the soil.
- The root can go deeper than three meters. the total root lenght varies by varieties and species in addition to growing conditions.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Root

- On average , roots makes up one fifth of the dry weight of a plant.
- Smallfibrous roots start to die as the plant enters into its heavy boll-load stage any beyond.
- Roots grow rapidly during seedling development and nearly attain their maximum lenght by the time the plant enters the reproductive stage.

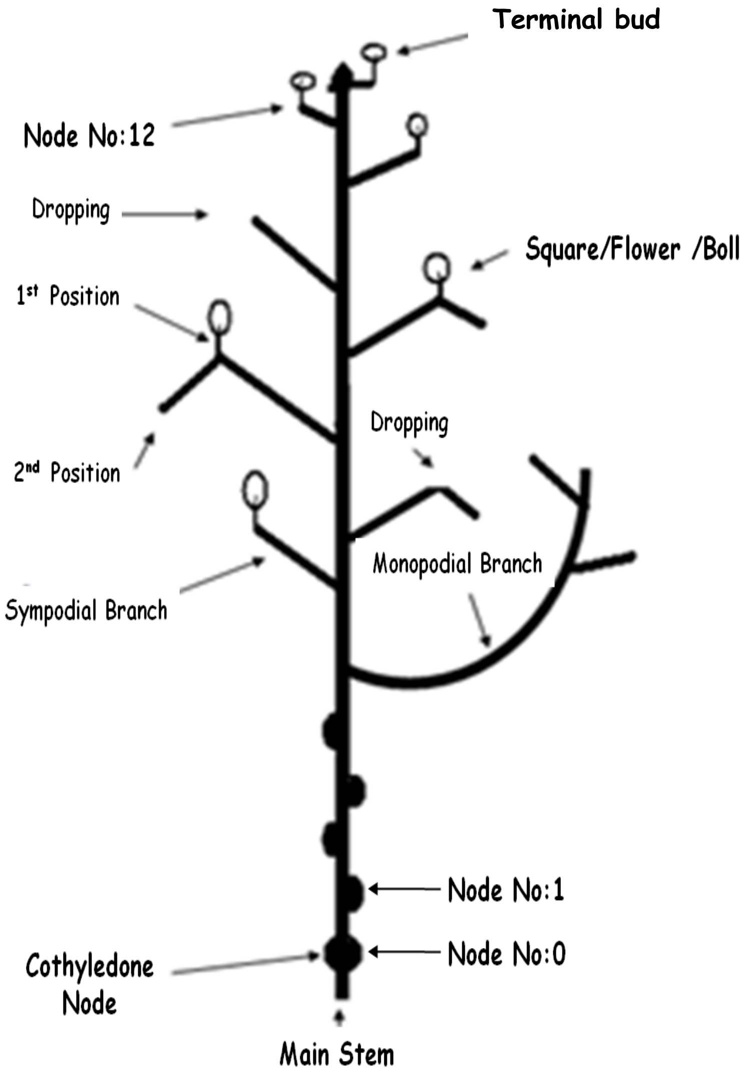
Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Root

- Root depth is almost six times the height of the shoot at thirty days after planting.
- At this stage the lateral growth is only 2,5 to 3 times the height of the plant.
- In most cultivated varieties,
  - 40% of water needs is absorbed by the top one-quarter of the root system,
  - 30% by the second quarter, 20% by the third quarter and
  - only 10% by the fourth quarter.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

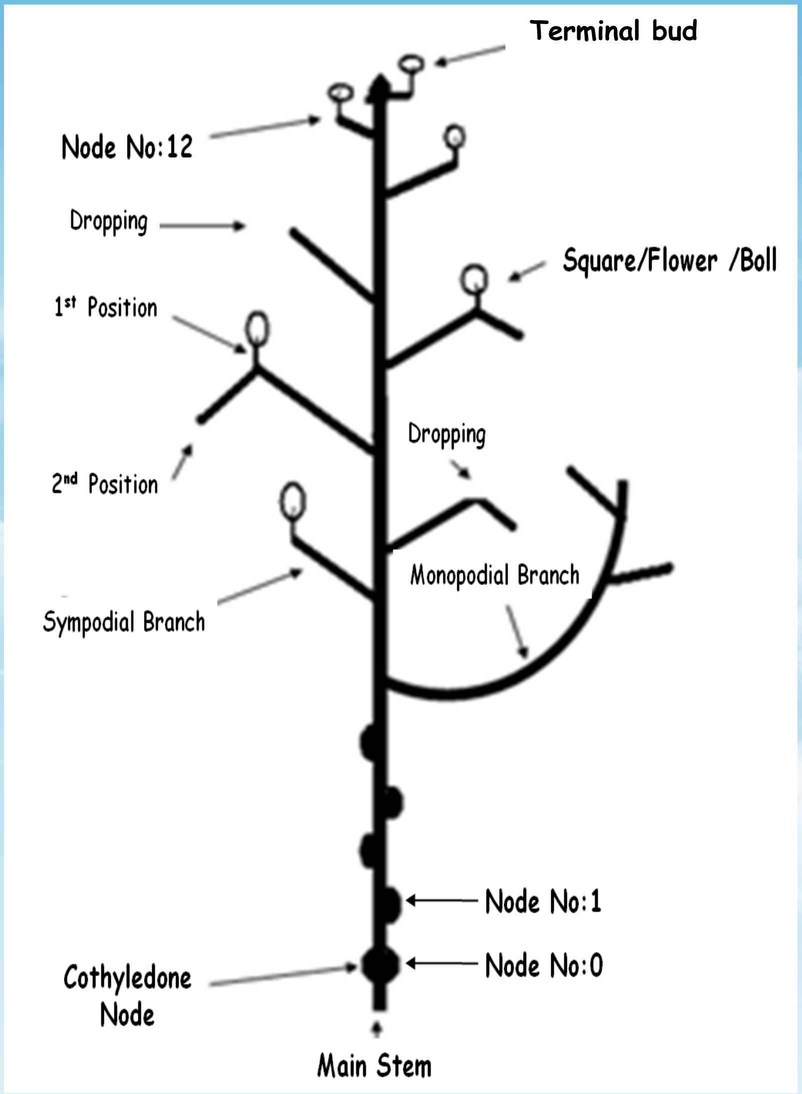
Shoot System



- The shoot system of the cotton plant is made up of a main axis stem, leaves, buds, branches, floral buds, flowers, and bolls.
- The prominent main stem, or primary axis, results from the elongation and development of the terminal bud or shoot apical meristem.
- The main stem consists of a series of nodes, where leaves are attached, and internodes.

Oosterhuis and Jernstedt (1999)

Shoot System



- The main stem has an erect, indeterminate monopodial growth habit.
- The number of nodes, the length of the internodes, and the number and location of branches is determined by genetic and environmental factors including cultural practices.
- The shoot system of a dormant cotton seed typically consists of the paired cotyledons, the primordium of the first true (foliage) leaf, and a dome of meristematic cells, the shoot apical meristem.

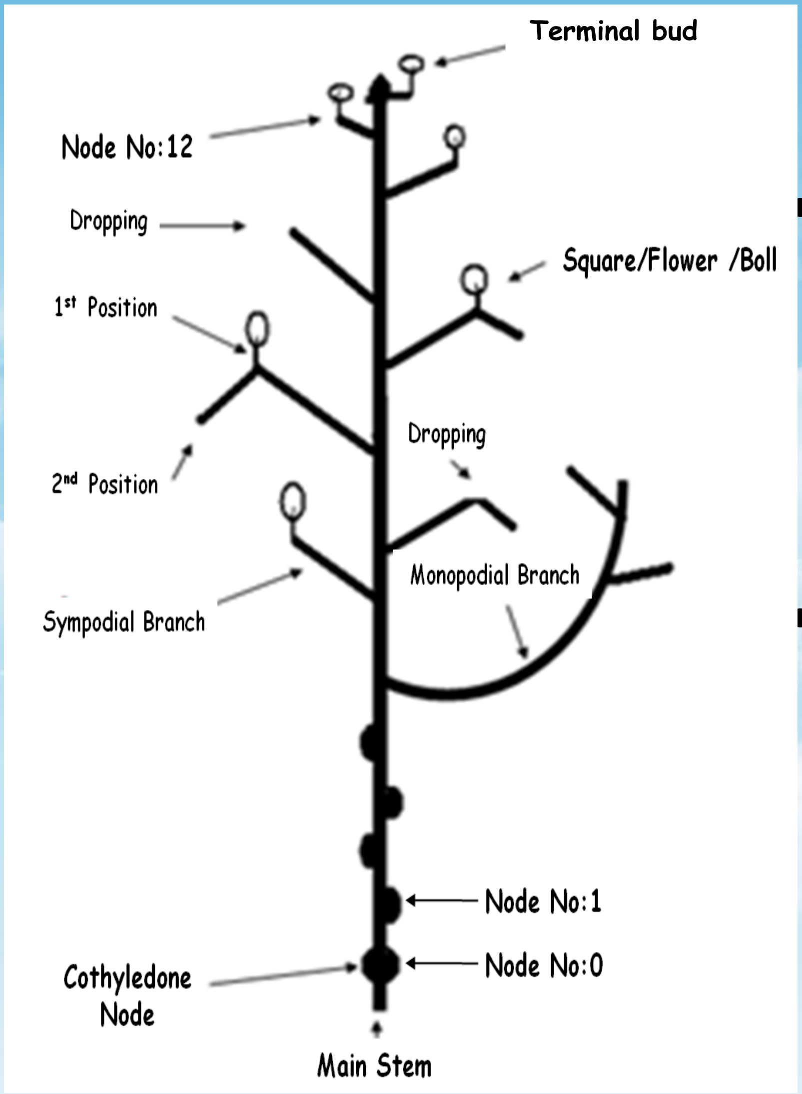
Oosterhuis and Jernstedt (1999)

Shoot System

- Cotton shoot apical meristems are quite typical when compared to other dicotyledonous plants.
- The portion of the axis above the cotyledons, the epicotyl, is extremely reduced, and it comprises a single shortened internode and one node.
- Thus, all subsequent leaves, nodes, internodes, and axillary buds and branches develop following germination.

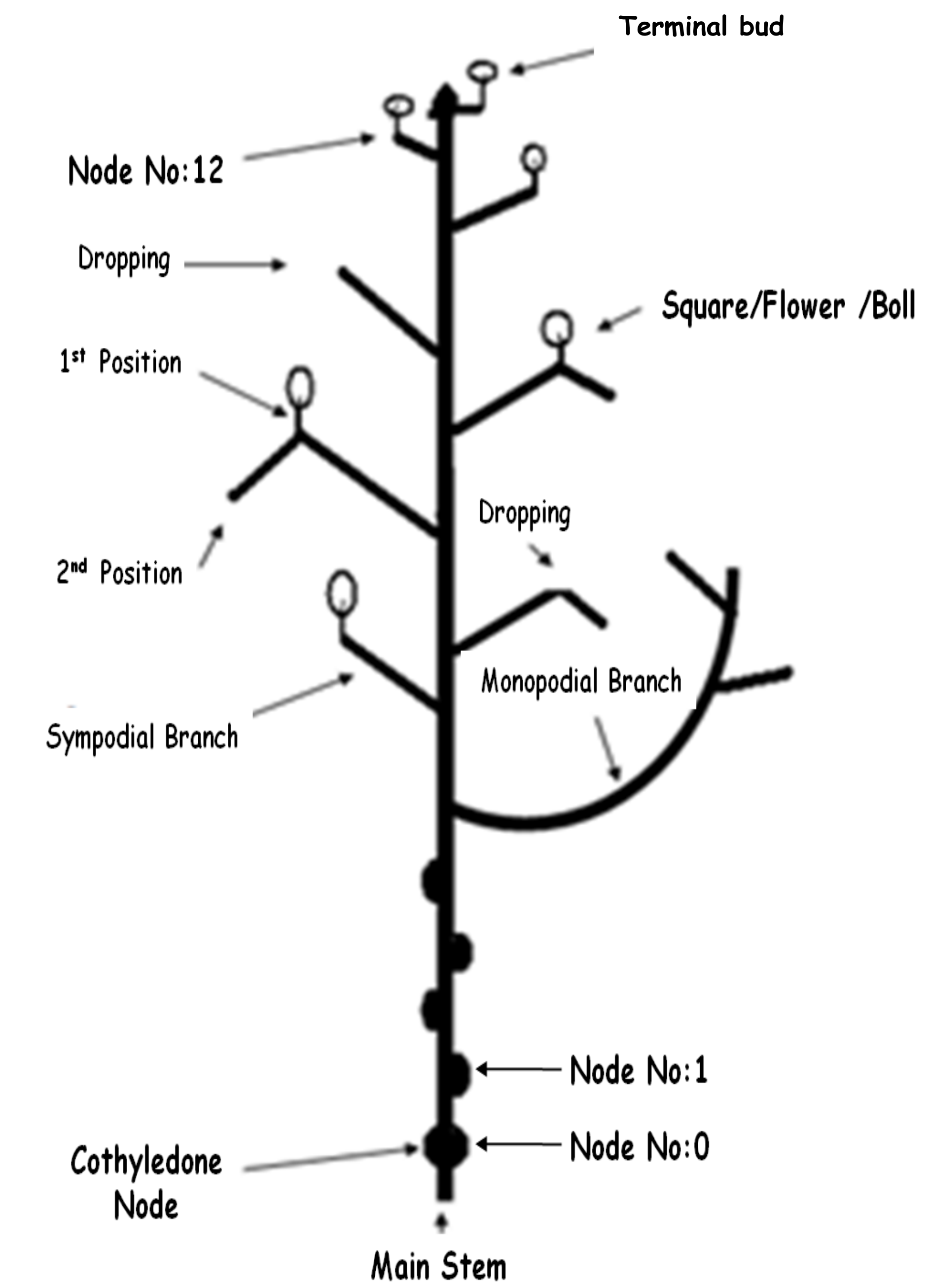
Oosterhuis and Jernstedt (1999)

Shoot System



- Seedling growth is relatively slow immediately following germination.
- Leaf initiation and expansion and internode elongation result in an unbranched plant with 4 or 5 expanded internodes about 1 month after planting.
- However, shoot growth during the subsequent 4 weeks is relatively rapid, so that by approximately 65 days after planting, 9-10 mature nodes and 5 or 6 elongated sympodial branches are present.

Oosterhuis and Jernstedt (1999)



Nodes

- The main stem of the cotton plant comprises many nodes, each capable of producing a branch.
- Except under very rare conditions, each node above numbers 5-7 produces a fruiting branch.
- The distance between two nodes is called internodal lenght. The internodal lenght is a genotypic character but depends highly on growing conditions.

Chaudry and Guitchounts (2003); Beahlman and Sloper (1995)

Nodes

- The three main factors responsible for longer internodal lenght are frequent
  - irrigation/rain,
  - excess supply of nitrogen and
  - inability of the plant to retain fruit (due to heat sterility, insects and other factors).
- The internodal lenght is reduced due to a shortage of water and other stresses.
- The internodal lenght starts to increase as the stress subsides.
- The number of nodes produced decreases with a delay in the sowing season.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Nodes

Cotyledonary Node

- For physiological assessment and monitoring purposes, nodes are usually numbered from the bottom to the top of the plant.
- The cotyledonary leaves from the first node on the main stem, which is the only node that never has a branch on it.
- Generally, under the close spacing conditions of a crop, a number of subsequent nodes (5-6) do not bear branches either, unless the terminal of the plant damaged.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Nodes

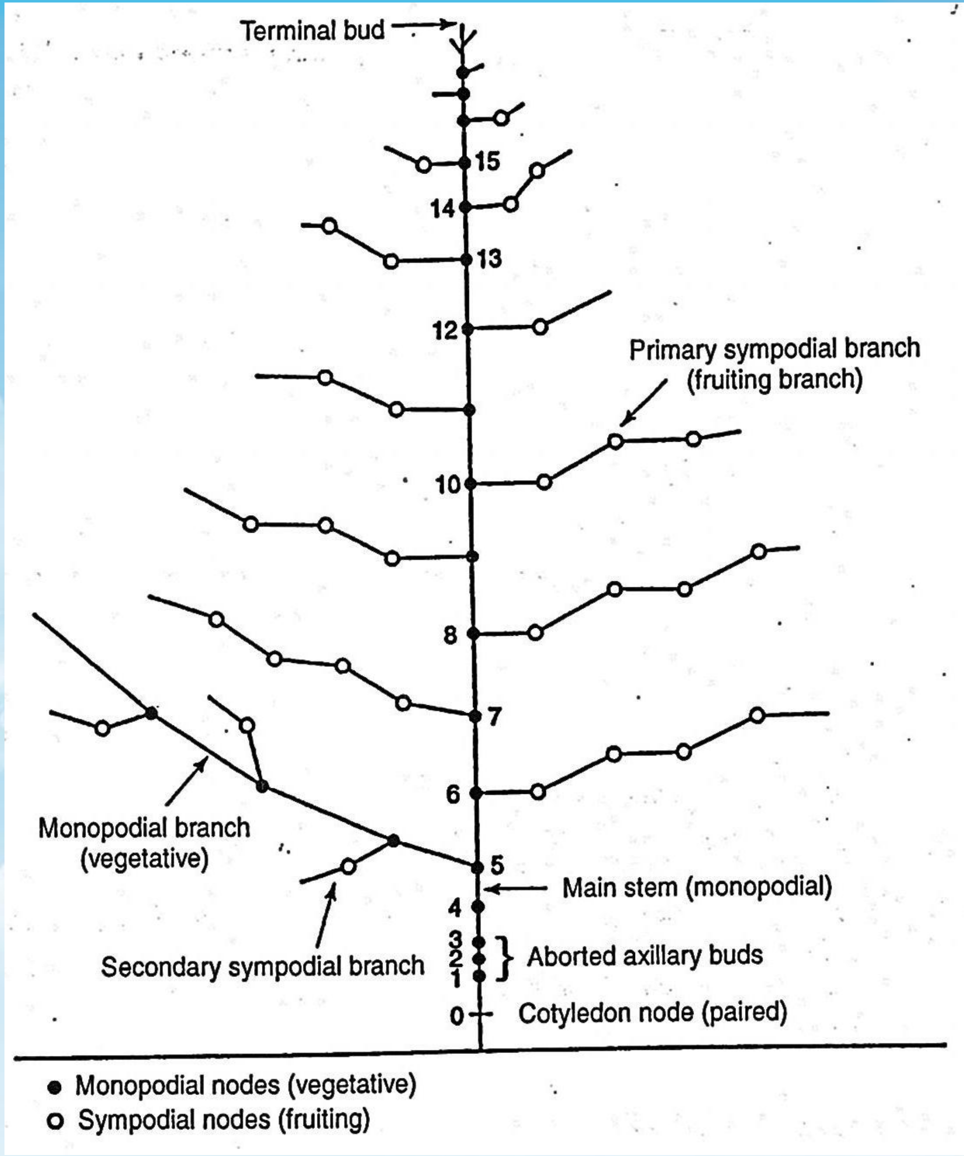
Cotyledonary Node

- The first node above the cotyledonary leaves is always longer.
- The next nodes have almost equal internodal lenght and then the lenght starts increasing and
- ultimately decreasing close to termination of growth.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Branches

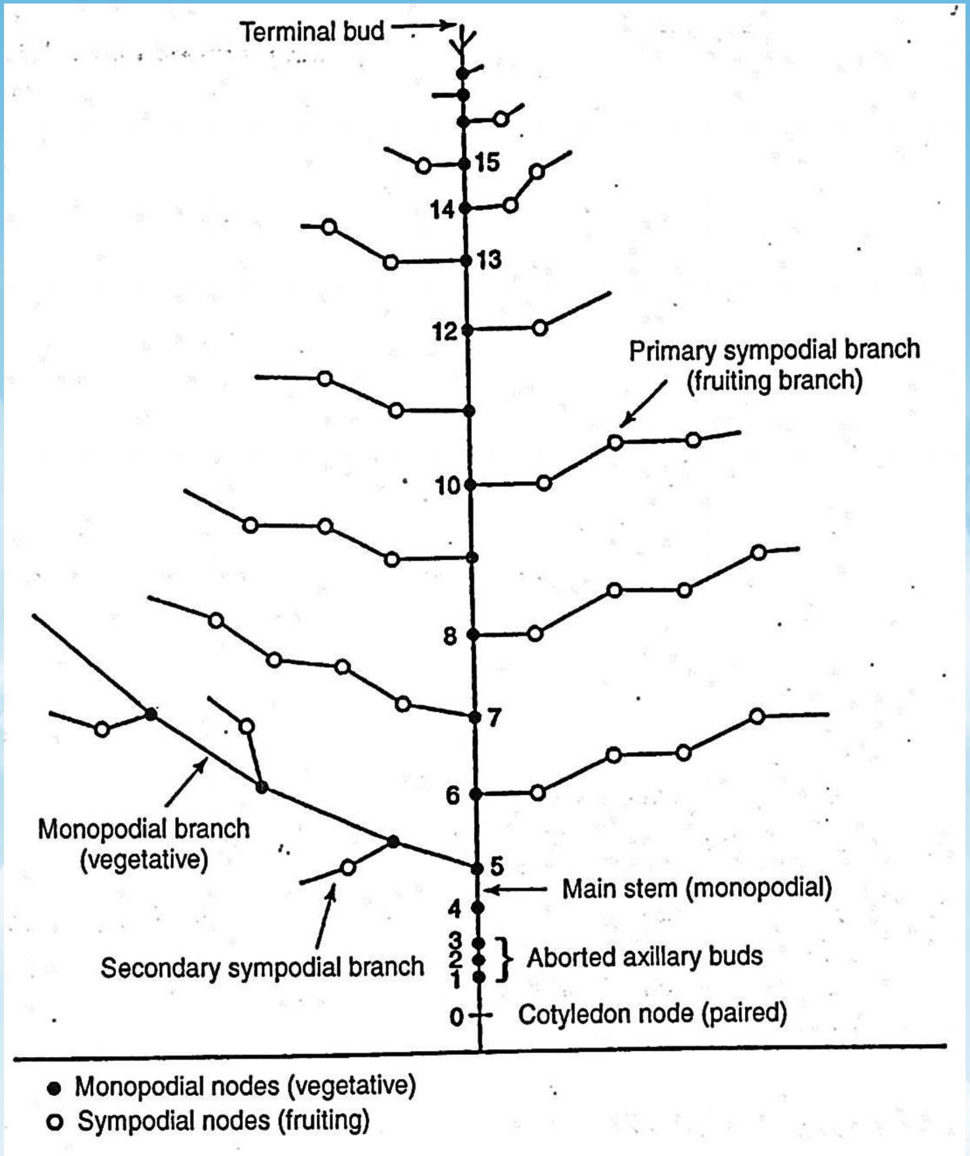
- Branches on the main stem are located in a spiral order, angled along the main stem.
- The cotton plant has two types of branches: monopodial and sympodial.
- Some genotypes may have both monopodial and sympodial branches, while others may have only sympodial branches.



Oosterhuis and Jernstedt (1999); Chaudry and Guitchounts (2003

Branches

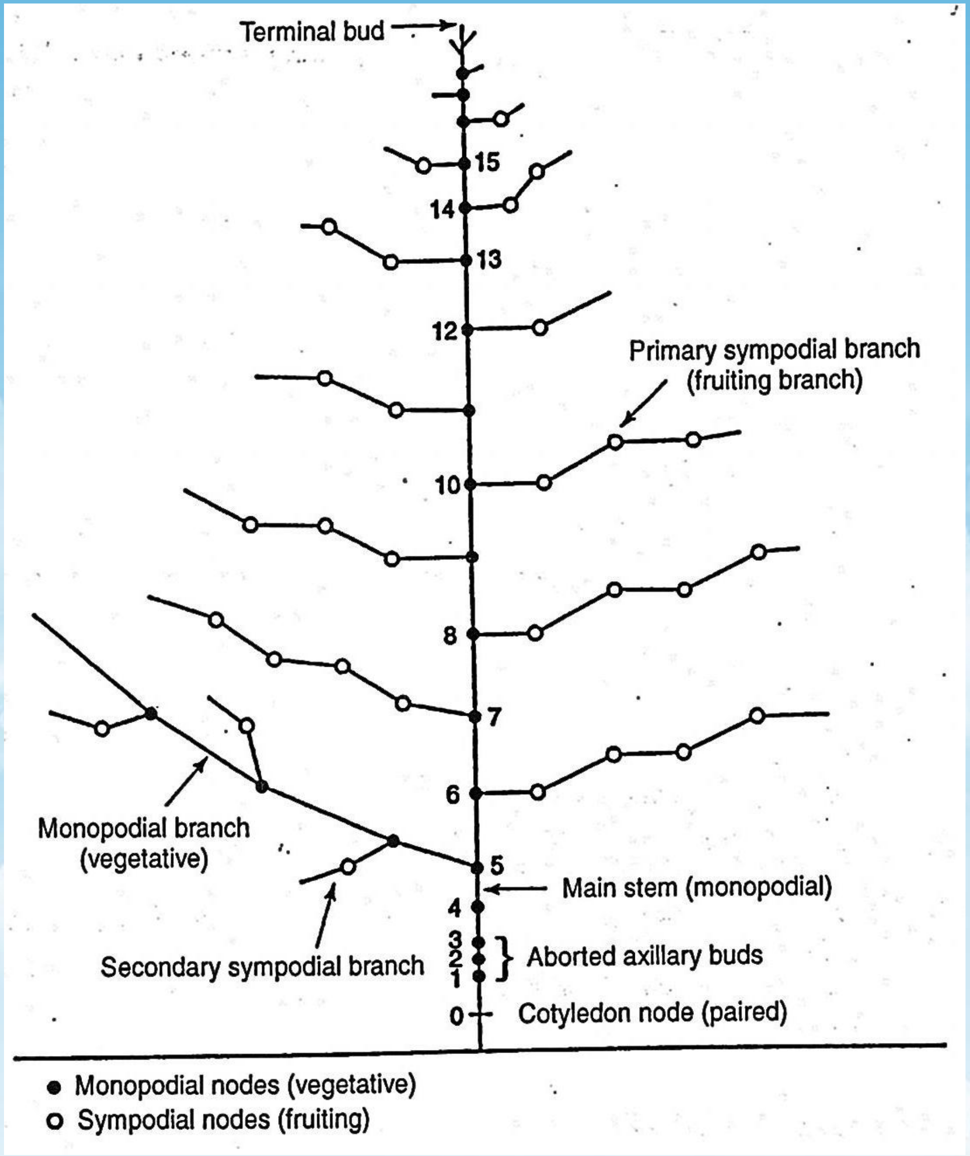
- Monopodial branches are larger than sympodial branches.
- The distance between the last monopodial branch and the first sympodial branch is only one internodal lenght.



Oosterhuis and Jernstedt (1999); Chaudry and Guitchounts (2003

Monopodial Branches

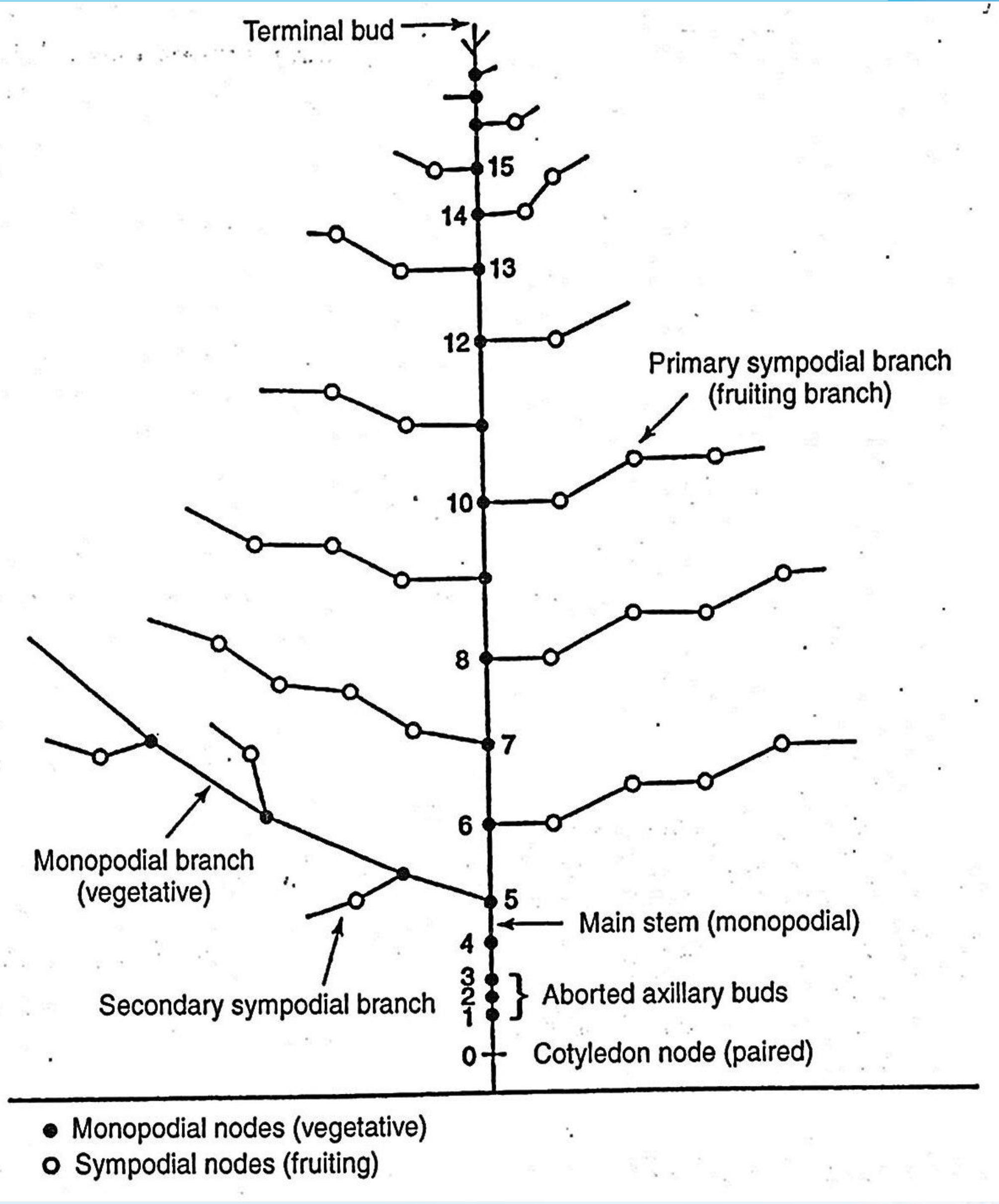
- The branches that do not bear fruit directly are the monopodial branches.
- Monopodial branches are also called vegetative branches and are always formed at the base of the cotton plant.



Oosterhuis and Jernstedt (1999); Chaudry and Guitchounts (2003

Monopodial Branches

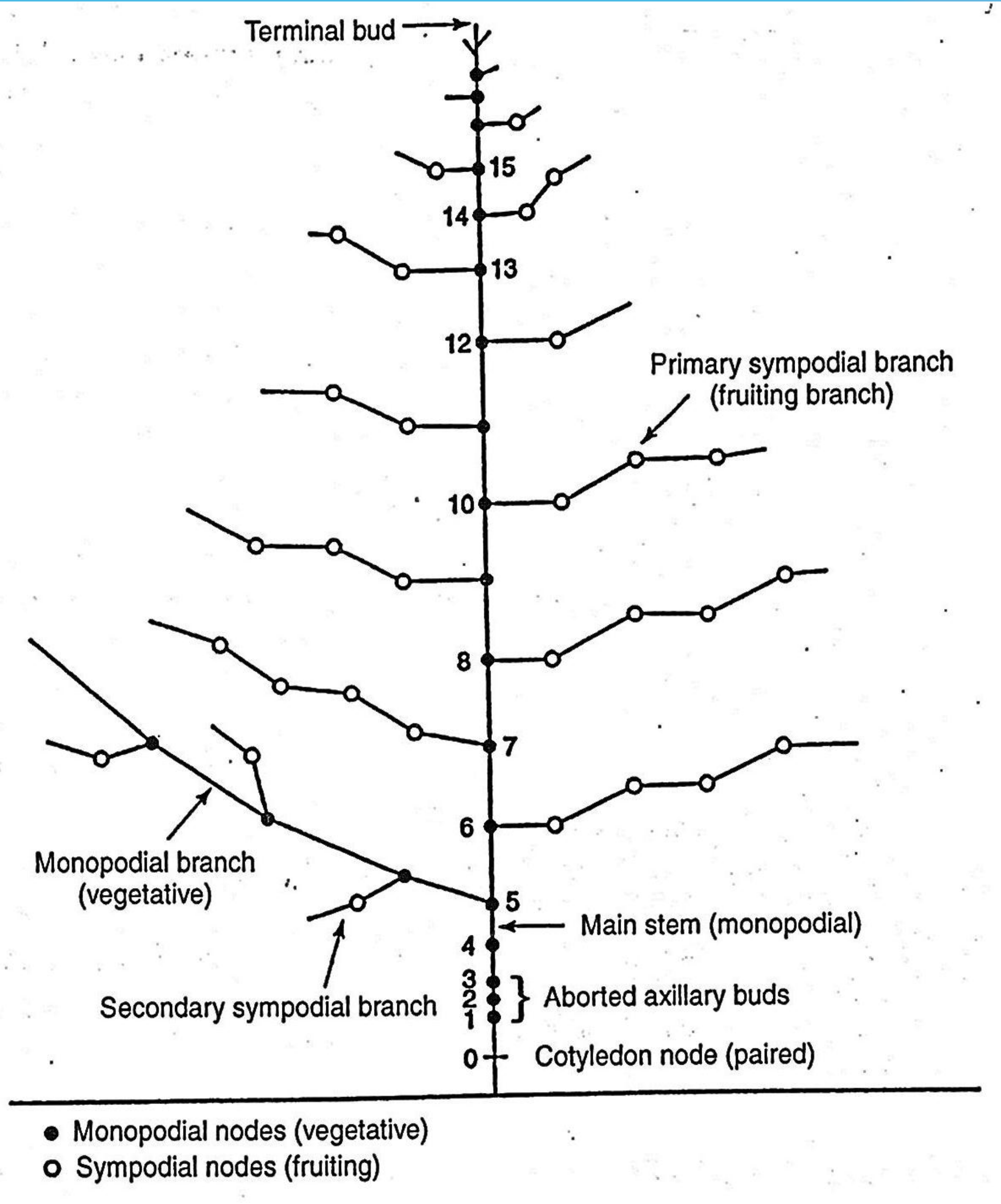
- Monopodial branches give the plant a bushy look and usually result in a slow rate of boll formation compared to a sympodial-type plant.
- Plant spacing has a great influence on the number of monopodial branches.
- Closer spacing reduces the apperance of monopodial branches.



Oosterhuis and Jernstedt (1999); Chaudry and Guitchounts (2003

Sympodial Branches

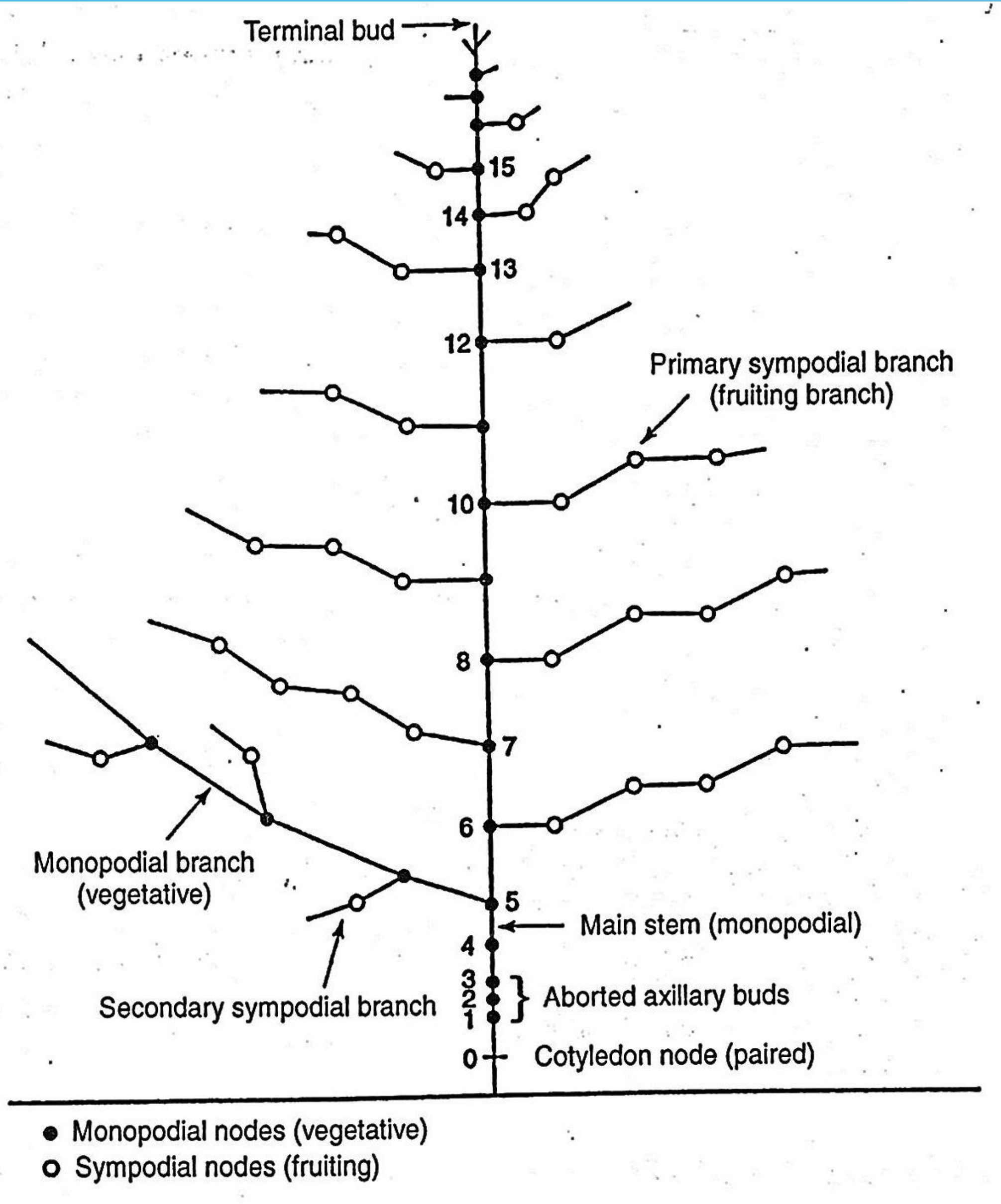
- Sympodial branches bear fruit directly, so they are called fruiting branches.
- The secondary branches on monopodial branches are also sympodial and bear fruit directly.
- Once a sympodial branch has formed on the main stem, one or two branches are formed on every subsequent node until the plant is physiologically exhausted and growth terminates.



Oosterhuis and Jernstedt (1999); Chaudry and Guitchounts (2003

Sympodial Branches

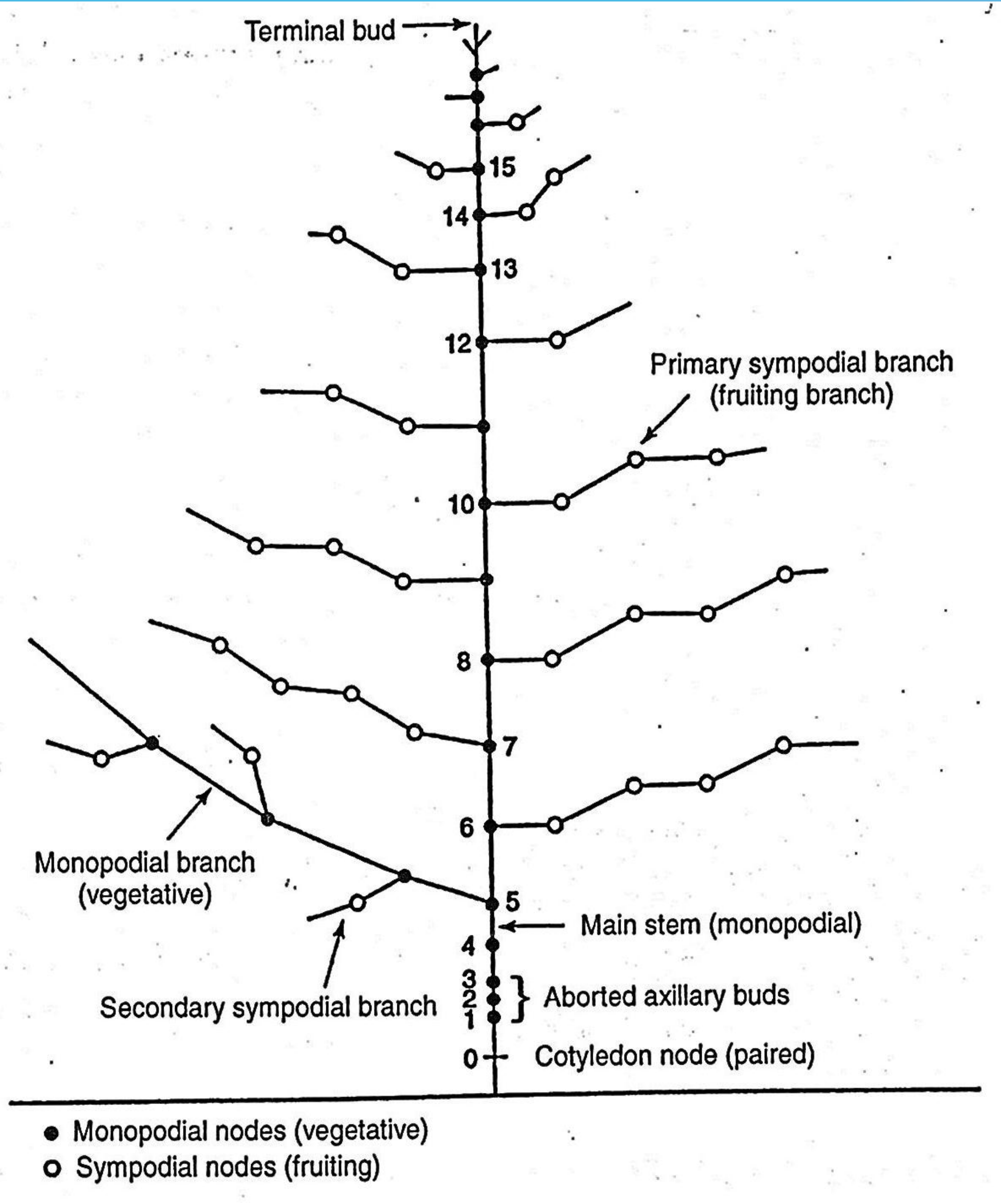
- Once a sympodial branch has formed at a main stem node, the plant is no longer able to produce monopodial branches above that node.
- The node at which the first sypodial branch will appear is a varietal character, but it is also affected by agronomic practices and treatments.
- Most sympodial branches are primarily branches, but they may have secondary or tertiary branches.



Oosterhuis and Jernstedt (1999); Chaudry and Guitchounts (2003

Sympodial Branches

- Cultivated varieties have a higher number of sympodial branches than monopodial branches.
- Plants with only sympodial branches enter into the fruiting phase of growth earlier than plants/varieties also having monopodial branches.



Oosterhuis and Jernstedt (1999); Chaudry and Guitchounts (2003

Leaves

- The cotton plant has two kinds of leaves: cotyledonary leaves and true leaves.
- Cotyledonary leaves emerge before the true leaves. The cotton seed has two well-developed cotyledons.
- The two cotyledons always form the first green leave.s Cotyledonary leaves have a rounded shape and have a short life, shortest among all leaves on the plant.

Cotyledonary leaves

True leaves.

Eksi (2004); Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Leaves

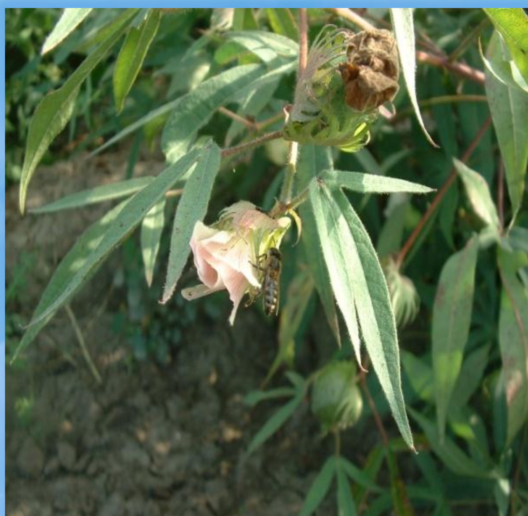
- Cotyledonary leaves are almost always two in number.
- On very rare occasions an abnormal embryo will have three cotyledons.
- Cotyledonary leaves appear to be attached to the stem directly opposite each other but in fact one is placed slightly above the other.
- One Cotyledonary leaf falls off before the other with a margin of three to ten days.

Leaves

- Cotyledonary leaves have a maximum life of 40 days. They are thicker than true leaves and do not have pointed edges like true leaves.
- The main stem emerges from the middle of the Cotyledonary leaves.
- True leaves have pointed edges from the beginning. By the time the first true leaf unfolds, 6-7 other leaves have already been formed.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Leaves



- True leaves have 3-5 lobes. The cuts (lobe sinus) may be deep or may only be half cut.
- Leaves with deep sinuses provide more aeration in the crop canopy and are called "okra type" and "super okra," depending on the size of the sinuses.
- Okra and super okra leaves, due to deeper cuts, may have a higher perimeter but a lower leaf area index compared to broad leaves.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Leaves

- True leaves reach their functional maturity in about twenty days and then begin to support other growing organs, including bolls.
- On average, leaves continue this support for the next forty days. Premature yellow leaves are usually half as thick as normal green leaves.
- The cotton plant has a spiral phyllotaxy (arrangement of leaves on the main stem).
- Every leaf is located at a three-eighth turn from the last leaf.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

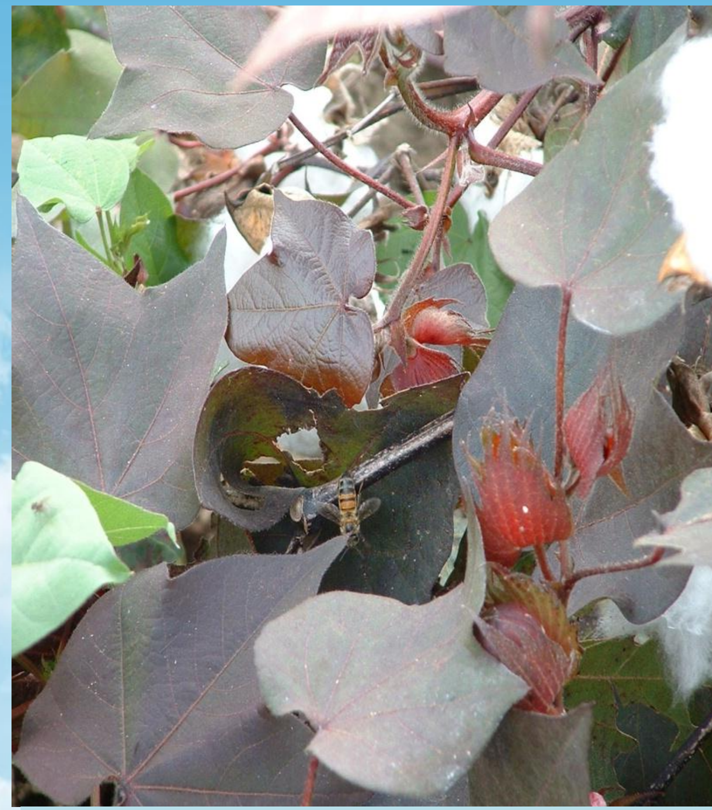
Leaves

- The arrangement can be clockwise or counterclockwise in the ultimate ratio of 1:1.
- Each leaf axel above node 5-7 has at least two buds, which at different times gives rise to a sympodium.
- The second bud often produces only a single fruiting point that may or may not abscise, or the bud may fail to break dormancy altogether.
- *G. barbadense* has the biggest leaves among cultivated species.

G. barbadense L.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Leaves

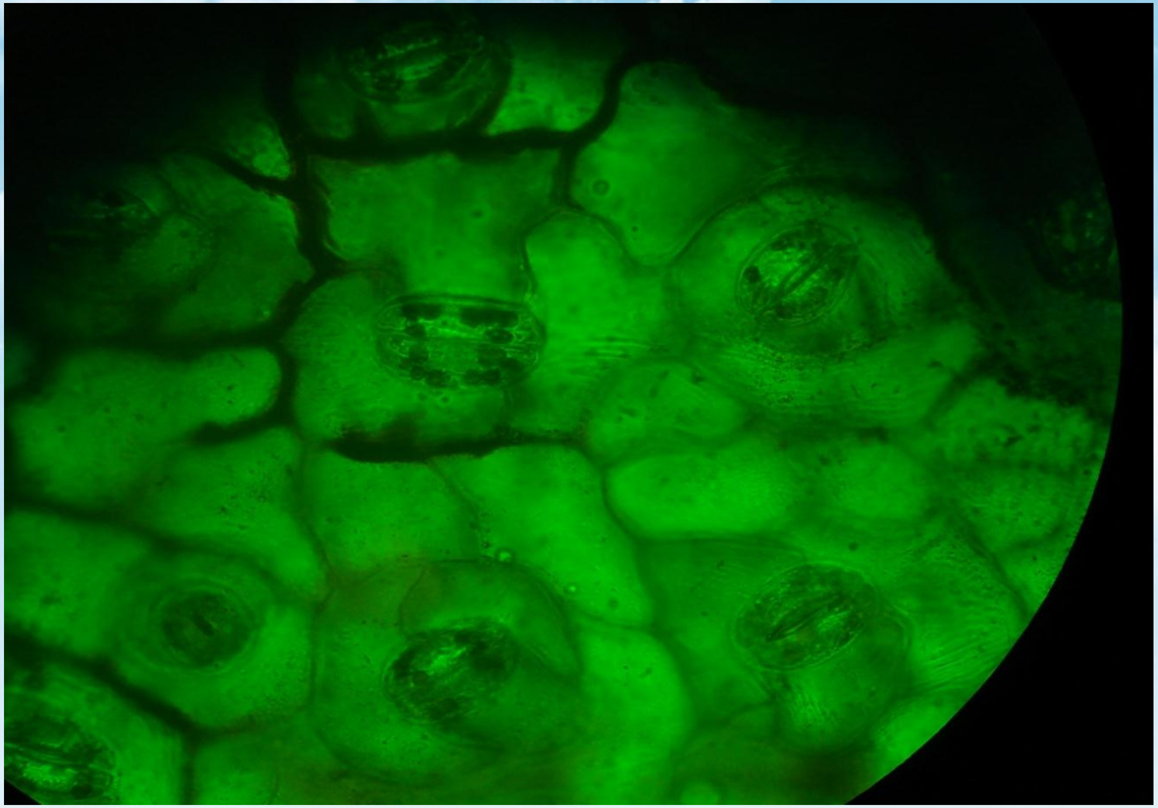


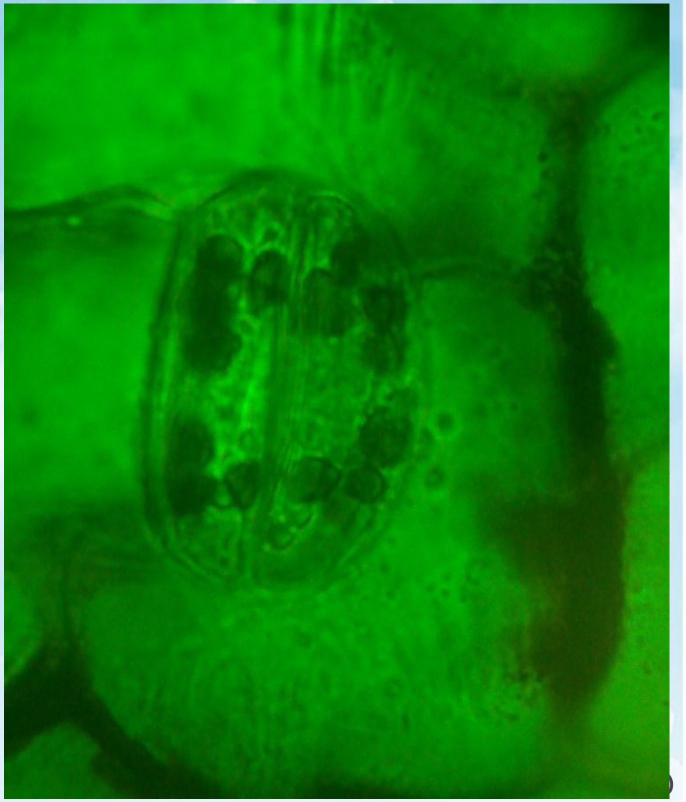
Dark Red Leaf Cotton cv *G.hirsutum* L. Mc Namara

A full-grown leaf is 12-15 cm in length and width. Leaf color in cotton plants may be various shades of green or dark red.

Leaves

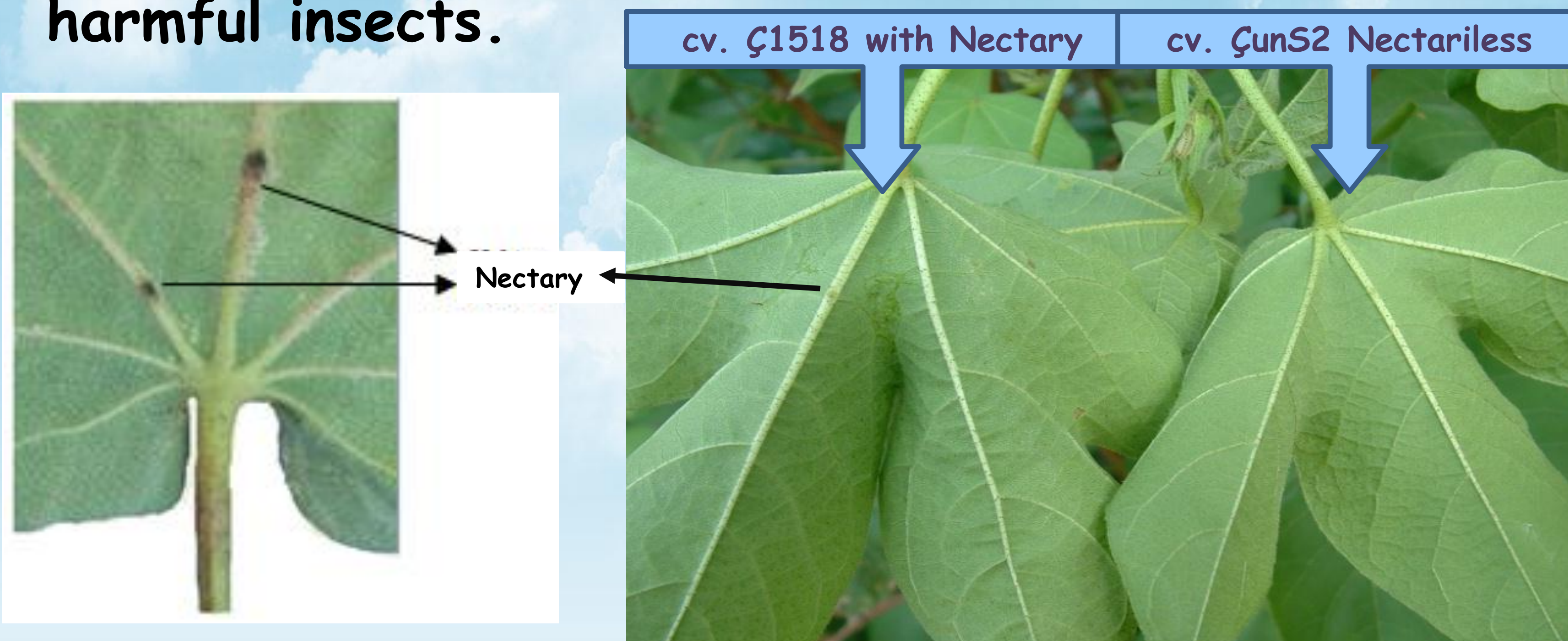
- The upper surface of the leaf has 2-3 times more stomata than the lower surface, with
    - 100-130 stomata/cm^2 on the upper surface and
    - 40-50 stomata/cm^2 on the lower surface.





Leaves

- Leaves may have nectary on the underside of the main rib, or they may be without nectaries.
- The nectary secretes sugary contents that may contribute to stickiness in cotton and also provides nutrition for multiplication of certain beneficial and harmful insects.



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Leaves

- Leaves of most cultivars have hairs. Hair density varies by species and variety; however, 20 to 22-day-old leaves have the highest hair density.
- Leaf hairs start falling as they age.
- Higher hair density usually results in higher amounts of trash in harvested lint, particularly in machine-picked cotton.
- Some bollworms prefer hairy leaves rather than smooth leaf varieties.
- Hairy varieties are preferred by whitefly. Late sowing reduces leaf hairiness. 2

Examples of trichomes typically associated with bract margin (A), abaxial leaf (B), leaf margin (C), and of Upland cotton. Hornbeck and Bourland (2007)

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Leaves

- Leaves have many functions.
- Leaves support other organs for various nutritional requirements.
- The cotton plant absorbs water, nitrogen and other nutrients from the soil.
- Leaves transform these nutrients from an inorganic form to organic substances through photosynthesis.
- Leaves store potassium for use during boll maturation when the plant is unable to meet potassium needs from the soil.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Leaves

- The plant has the highest need for potassium at the time of boll maturation. Leaves also absorb systemic insecticides and save the plant from pest damage.
- The condition of the plant's leaves reveals much about the needs of the plant.
- Leaves are the strongest indicators of the need for irrigation.

From the Institute project of 'Researches on Effect of Some Agronomic Applications on Plant Monitoring Parameters and Plant Mapping of Cotton' Toklu et. al. (2009)

95)

Leaves

- They are indicators of pest attack and of the need for insecticide application.
- Hairy leaves protect against attack by some insects, but are preferred by other insect pests.
- Leaves also serve as indicators of nutrient deficiency.
- Normal leaves have the highest amount of nitrogen among all above-ground parts (excluding seeds) of the plant.

Leaves

- With age, the nitrogen level decreases by almost 50%- less than in the seed.
- The reason for the decrease in nitrogen is its translocation from older to younger tissues.
- There may not be bolls on the plant, yet the plant could have normal leaf size and number.
- Water-stress affects leaf area more than photosynthetic rate.
- Soil salinity affects photosynthesis and stomatal conductance.

From the Institute project of 'Researches on Effect of Some Agronomic Applications on Plant Monitoring Parameters and Plant Mapping of Cotton' Toklu et. al. (2009)

Leaves

- Excessive doses of nitrogenous fertilizers increase leaf area but do not add proportionally to the leaf dry weight.
- Leaves may exhibit three types of shedding: premature shedding, normal/age shedding and forced shedding.
- This process is supported by an abscission layer, which is a layer of specialized cells.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Leaves

- It is formed between the leaf petiole and the main stem or branch in response to nutrition, water, or some other stress.
- Abscission occurs when the cells in the layer expand, cell walls dissolve and the mechanical weight of the leaf causes it to fall.
- Many factors, including physiological and environmental, could force the leaves to shed before they reach the age of normal shedding.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Leaves

- Abscission is the process which causes the plant to shed its leaves.
- A change in hormone activity is also responsible for leaf shedding.
- A number of other factors also enhance the formation of the abscission layer.
- Spraying certain chemicals called defoliants can also enhance formation of the abscission layer.
- Defoliation is generally a prerequisite for machine harvesting.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Flower

Gossypium barbadense L.
Image processed by Thomas Schoepke
www.plant-pictures.de

Flower

- The cotton plant has a complete flower, surrounded by bracteoles, with a well developed calyx, Corolla, gynoecium (female flowerparts) and androecium (male flower parts).
- The cotton flower has three bracteoles inserted above the nectaries around the flower base.
- Bracteole size depends on genotype and ranges from 1-3 inches in lenght and width among cultivars.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Flower

- Bracteoles have many deep cuts (teeth), are green in color, and do not change their color significantly until the boll is ready to open.
- The calyx is cup shaped with five teeth indicating five sepals united into one.
- The Corolla has five large petals tapering toward the bottom.
- Generally petals are showy, white, white-creamy in G.hirsutum.

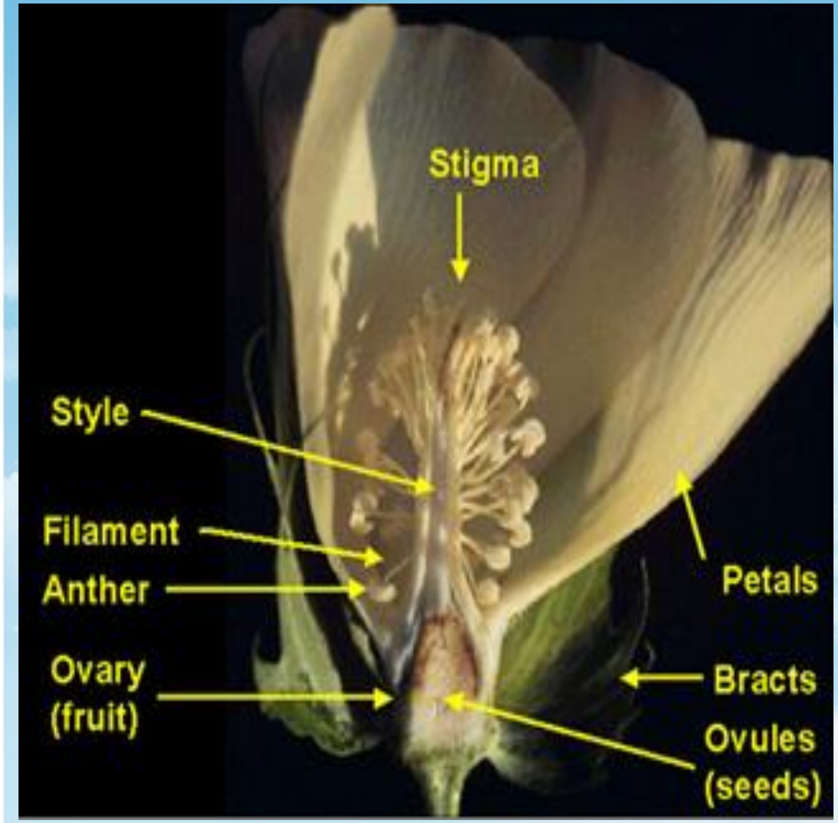
Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Flower

- The petals of *G. barbadense* are usually bright yellow.
- Petals sometimes have a dark rose-colored spot at the base in *G. hirsutum* and almost always in *G.barbadense*.
- Petals are closed in a whirl until the day of anthesis.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

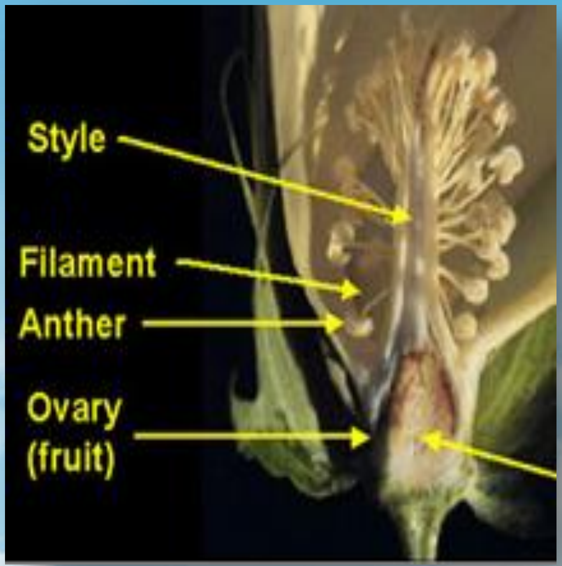
Flower



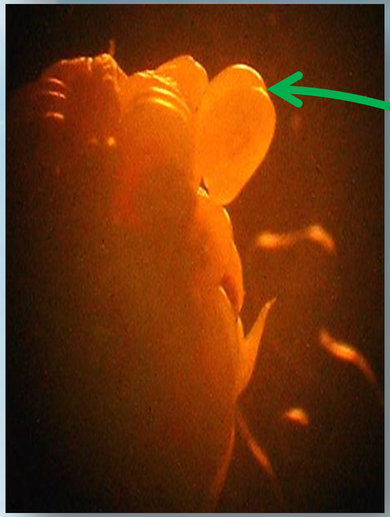
- Stigma, styl and ovary form the female part of the flower in cotton.
- The ovary comprises 3-5 carpels, forming the corresponding number of locules in the boll.
- Each carpel has a number of ovules (depending on genotype) arranged in two vertical rows.
- The number of fertilized ovules corresponds to the number of seeds in each locule if fertilized ovules were not aborted.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

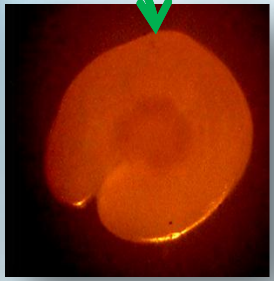
Flower



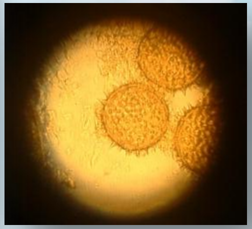
- Stamens, which form the male part of the flower, are numerous.
- The lower parts of the stamen filaments are united in a tube. the upper parts contain anthers bearing pollen grains.
- Pollen grains are round and have spikes. Their color is creamy or creamy yellowish in G. hirsutum and yellow in G. barbadense.



Flower Bud



Anter



Microspor

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Flower

- The flower bud is the first organ that lays the foundation for lint and seed production on the plant.
- On average, a flower bud matures into a flower in about 25 days.
- As the flower readies to open, petals push the bracteoles apart to emerge.
- Opening or unwhirling of petals is an indication that the flower is ready for dehiscence of anthers and pollination of ovules.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Flower

- Petals continue to grow for 10-25 hours even after the flower has opened but at a much slower rate than before opening.
- Petals change color to pink on the day of opening . The change in color happens irrespective of the fertilization process.
- Pollen grains are shed just before or soon after the petals open and expose anthers to direct light Bracteoles begin to dry after the boll has opened but do not fall off by themselves.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Flower

- Defloration increases the height of the plant.
- Cotton pollen grains cannot remain viable for a long time in storage.
- After twenty-four hours, storage of the open flower in a household refrigerator greatly reduces the the germinability of pollen grains.
- A flower bud collected the day before anthesis retains pollen viability for a longer time (a few days more)

Flower

- Pollination occurs so on after anthesis, but fertilization occurs 12-20 hours later.
- Many pollen tubes grow on the stigma, but not all of them reach the ovules.
- Thus, flower ovules mayor may not all become fertilized.
- At least one ovule must be fertilized ovules per flower may not be enough to hold the boll on the plant.




Flower

- Rainfall in the morning hours at the time of anthesis negatively affects seed setting efficiency because free water ruptures the pollen grains.
- Following pollination, the pollen tube growth rate is slow for the first two hours, then increases to a maximum of 3 mm per hour, with pollen tube growth being slowest in the ovary.
- Temperature has a crictical effect on pollen tube growth compared to light and humidity. The threshold temperature limits for proper pollen tube growth range from 15-50^{0}C.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Boll

- A fertilized flower takes about fifty days to become an open boll.
- Boll period is the duration from open bloom/flower to open boll.
- On average, a boll develops to full size 25-30 days after flowering.
- By then, seeds have also grown to full size. Heat units per day have a significant effect on the time taken to mature.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Boll

- Extremely low temperatures and frost dries green bolls on the plant.
- The boll period increases with a decrease in temperature.
- Night temperature is more important than day temperature.
- Boll weight is the weight of seedcotton picked from a single, naturally open boll.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Boll

- A boll may have 3-5 locules.
- In varieties that have the genetic ability to bear five-locule bolls, the proportion of the bolls increases toward peak flowering and decreases after boll load increases.
- Five-locule bolls are more liable to be dropped due to stress at an early stage than four-locule bolls.
- If a plant has five- and four-locule bolls, seeds from the five locules could produce five- and four-locule bolls.

Boll

- Seeds from a four-locule boll in a plant having five- and four-locule bolls may produce four- and five-locule bolls.
- The size, shape and smoothness of a boll’s surface vary greatly among varieties.
- *G. hirsutum* has the largest boll among cultivated varieties, followed by *G. barbadense*, *G. arboreum* and *G. herbaceum*.
- Most cultivated varieties produce the following boll weight:

Boll

Species	Range of Boll Weight
G. hirsutum	3.0-10.0gm
G. barbadense	3.0-5.0 gm
G. arboreum	1.0-4.0 gm
G. herbaceum	1.0-4.0 gm

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Boll

- Boll size is greatly dependent on climatic conditions; mild conditions produce bigger bolls. The shape of a boll ranges from round to oblong and pointed.
- "Hard loc" is a condition in which a boll or part of a boll cracks but fails to open fluffy.
- Fibers from hard locs are weak and immature and seeds do not have a fully developed embryo.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Boll

- Agricultural crops are grown for a variety of purposes.
- For example, potatoes are grown for their tubers, sugarcane for the sucrose in its juice, tobacco for its leaves, oranges for their juice, corn for its seed, and cotton only for an outgrowth (trichome) on its seed coat.
- Cotton is also grown for lint, and thus the quantity of lint produced per unit area is generally referred to as yield.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Boll

- However, for a farmer who sells seed cotton, seed cotton is yield, but for a farmer who sells lint, only lint is yield.
- Cotton yields are limited by constraints.
- The nature of constrains may be different in different countries or growing conditions.
- There are various ways of measuring yield as well, such as biomass, biological and economic yield, genetic potential and recoverable potential.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Boll

- Biomass is the total dry matter weight produced by the cotton plant. It includes root, stem, leaves, branches, all forms of fruiting parts and seedcotton.
- Biological yield is the dry matter weight of all above-ground parts of the cotton plant.
- Biomass less the dry matter weight of root is equal to biological yield.
- Economic yield in any crop/plant is the ultimate product for which a crop is grown.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Boll

- In the case of cotton, it is primarily lint.
- Genetic potential is an arithmetic calculation of yield based on the *genes* present in the *genotype*.
- The *genetic* potential of cotton varieties is not known.
- The recoverable potential is an upper limit yield that can be realized under a particular set of growing conditions.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

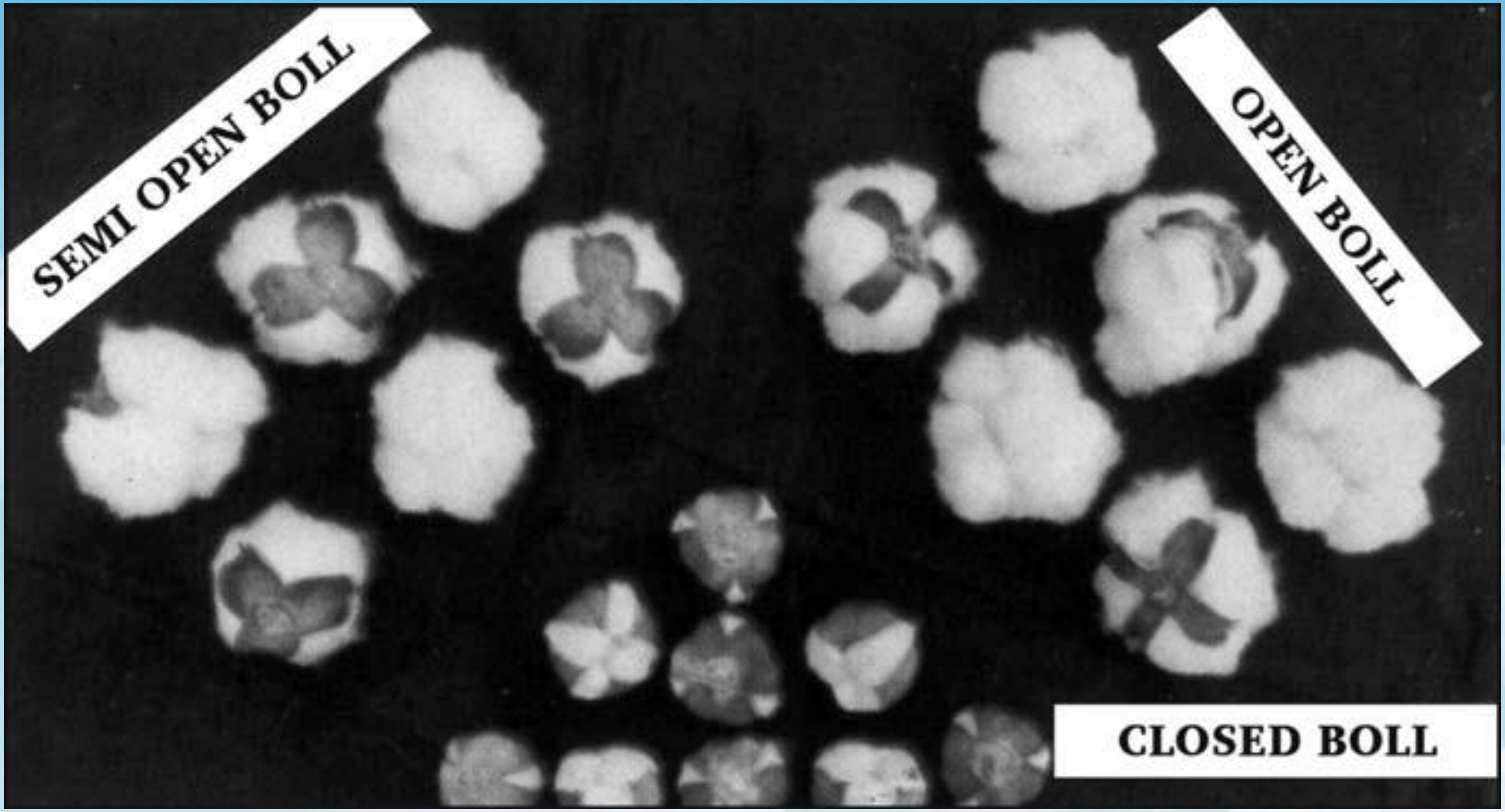
Boll

- A genotype can exhibit a higher recoverable potential under favorable weather conditions, while adverse conditions can inhibit the plant from expressing its genetic potential for economic yield.
- Thus, genotypic interaction with growing conditions determines the recoverable potential.
- The recoverable potential is always less than the genetic potential in cotton.
- The difference will be higher under unfavorable conditions and lower under conditions that are favorable for a genotype.

Boll

- Earliness in cotton is defined in many ways.
- It is defined as appearance of the first flower, early fruit formation/retention, early boll opening, termination of crop, seedcotton picked in the first pick compared to the total harvest, and completion date of final picking.
- The cotton plant, being indeterminate in nature, supports vegetative and reproductive growth at the same time during most of its life cycle.

Boll



Coverage of boll-rind after complete desiccation in closed boll (variety Dhummad), semi-open boll (variety G.Cot 17) and open boll type (variety Jaydhar) of G. herbaceum cotton

Kulkarni et al.(2009)

Boll

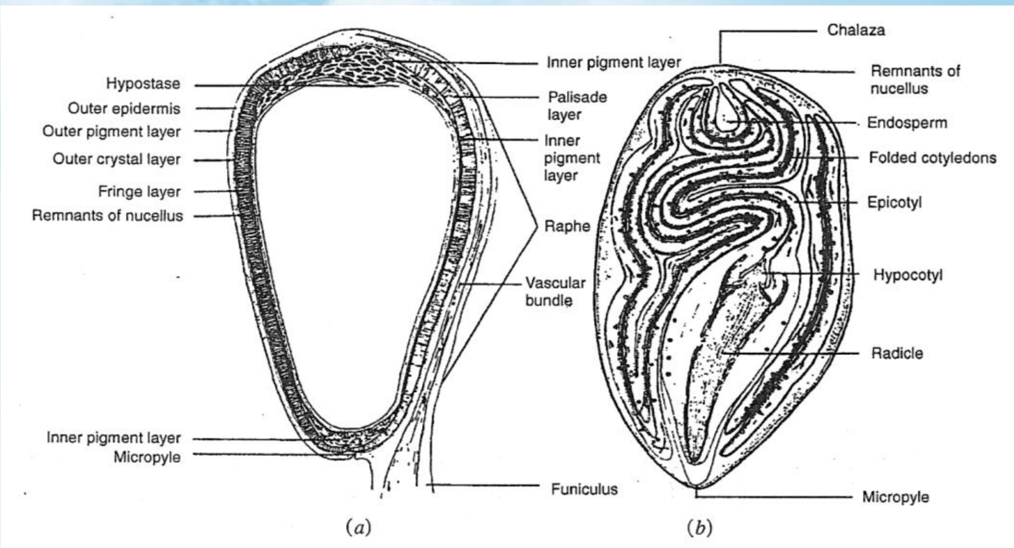
Dhummad variety of G. herbaceum having closed bolls cultivated in coastal salinity of Gujarat, India

Kulkarni et al.(2009)

Seed

Formation and Germination

- Technically, a seed in cotton is a fertilized ovule that may or may not mature into a full grown seed.
- Seed development can be divided into three stages: enlargement, filling and maturation.



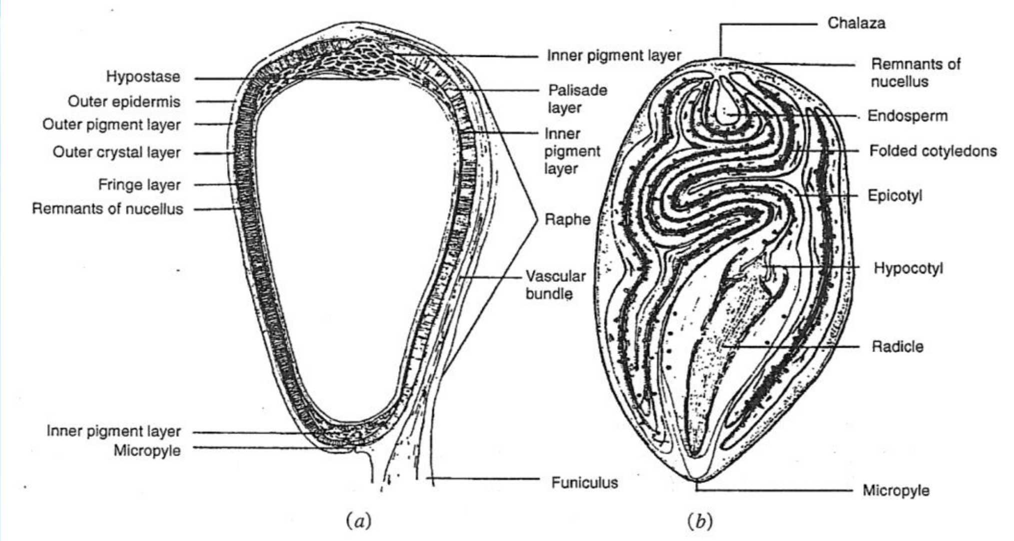
Structure of matura cotton seed

Oosterhuis and Jernstedt (1999) ;Chaudry and Guitchounts (2003

Seed

Formation and Germination

- Seed development is strongly related to potassium availability. In about three weeks, the fertilized ovule develops the size of a full-grown seed.
- During the next three weeks, the seed accumulates oil and proteins in the embryo during the filling stage.



Structure of matura cotton seed

- The maturation stage is characterized by significant physiological processing, including hardening of the seed coat.

Oosterhuis and Jernstedt (1999) ;Chaudry and Guitchounts (2003

Seed

Formation and Germination

- Seed size varies greatly among species and varieties. Seed size also varies within a variety.
- The average length and width of upland cotton seed is about 10 mm x 6 mm. *G. barbadense* seeds are smaller than *G. hirsutum* seeds, and they are mostly naked or have less fuzz.
- *G. arboreum* and *G. herbaceum* seeds are even smaller than
- *G. barbadense* seeds, but they are fuzzy.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995) ;Kulkarni et al.(2009)

Seed

Formation and Germination

- Seed index is the weight of 100 fuzzy seeds. *G. hirsutum* varieties have 7,000 to 8,000 seeds per kilogram.
- Unfertilized ovules make up the majority of motes, but some fertilized ovules may abort and form larger motes of various sizes.
- Seed can be stored for over five years if the moisture level is less than 10% and there is good aeration. The period of safe storage decreases with the increase in seed moisture content.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995) ;Kulkarni et al.(2009)

Seed

Formation and Germination

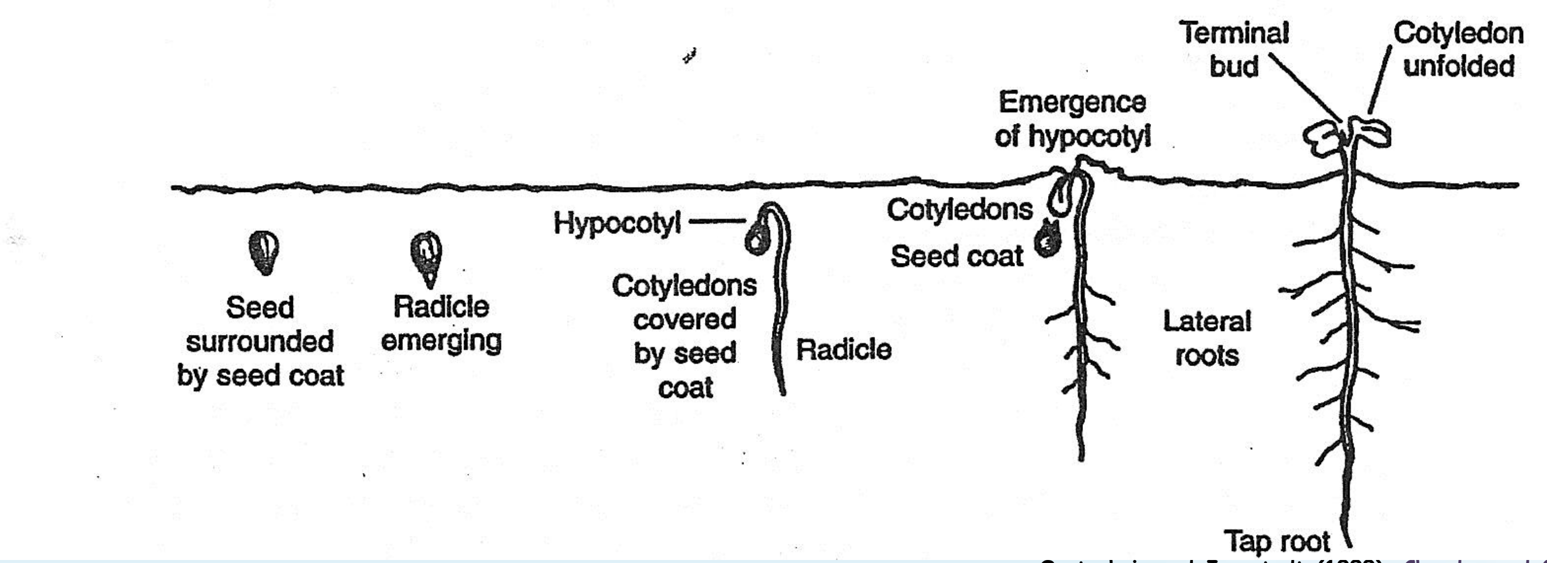
- Seed developed during humid conditions is more prone to deterioration.
- Seed harvested soon after boll opening has a dormancy period called the "quality conditioning" period.
- Cottonseed is usually dormant for 3-4 weeks. Abscisic acid inhibits germination and the rapidity of germination.

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Seed

Formation and Germination

- The appropriate depth for planting cottonseed is 3-4 cm. The germination process does not begin unless moisture is absorbed into the seed.
- If enough moisture is available, the radical emerges through the micropylar end of the seed in 2-3 days to form a root.



Oosterhuis and Jernstedt (1999) ;Chaudry and Guitchounts (2003

Seed

Formation and Germination

- Micropyle is a minute hole on the tip of the seed. The hypocotyl is the stem tissue between the radical and cotyledons.
- As soon as the radical is formed, hypocotyl cells expand and push the cotyledons out of the ground.

Oosterhuis and Jernstedt (1999) ;Chaudry and Guitchounts (2003

Seed

Formation and Germination

- The germination process is slow under low soil temperatures.
- For optimum germination under field conditions, soil temperature must be at least 60°F.
- At least 50-60 heat units are required for a seedling to emerge from the soil.
- Under optimum conditions in the field, the germination process is completed in about 6-8 days.

udry and Guitchounts (2003); Poehlman and Sleper (1995)

Seed

Composition

Product	Yield
Crude oil	16%
Hull	27%
Meal	46%
Linters	8%
Waste	3%

Chaudry and Guitchounts (2003); Poehlman and Sleper (1995)

Fiber

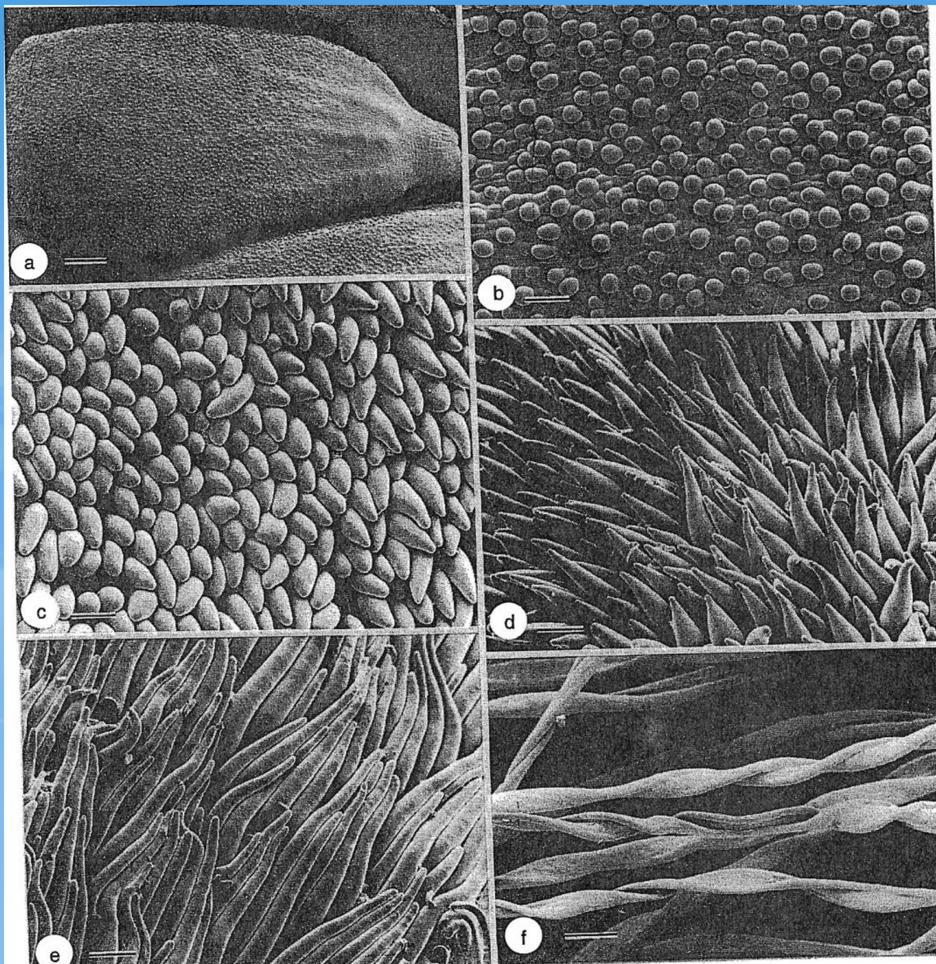


Figure 2.1.21. Fiber development. (*a*) Cotton ovule on the day of anthesis. (*b*) Fiber initials (primordia) on the day of anthesis. (*c*) Developing cotton fibers early on the day after anthesis (+1dpa). (*d*) Developing cotton fibers late on the day after anthesis (+1dpa). (*e*) Developing cotton fibers 3 days after white flower (+3dpa). (*f*) Mature cotton fibers (approximately +48 dpa). Scale bar = approximately 200 μm in (*a*), approximately 30 μm in (*b–f*).

- Cotton fibers are epidermal trichomes (hairs) that arise from the protoderm of the ovule.
- The protoderm is a primary meristem of the plant and, consequently, continues to undergo mitotic cell divisions for a number of days following anthesis
- In addition to hairs, cells of the protoderm differentiate and mature as stomata (guard cells and pore) and epidermal cells.

Stewart, 1975;Oosterhuis and Jernstedt (1999)

Fiber

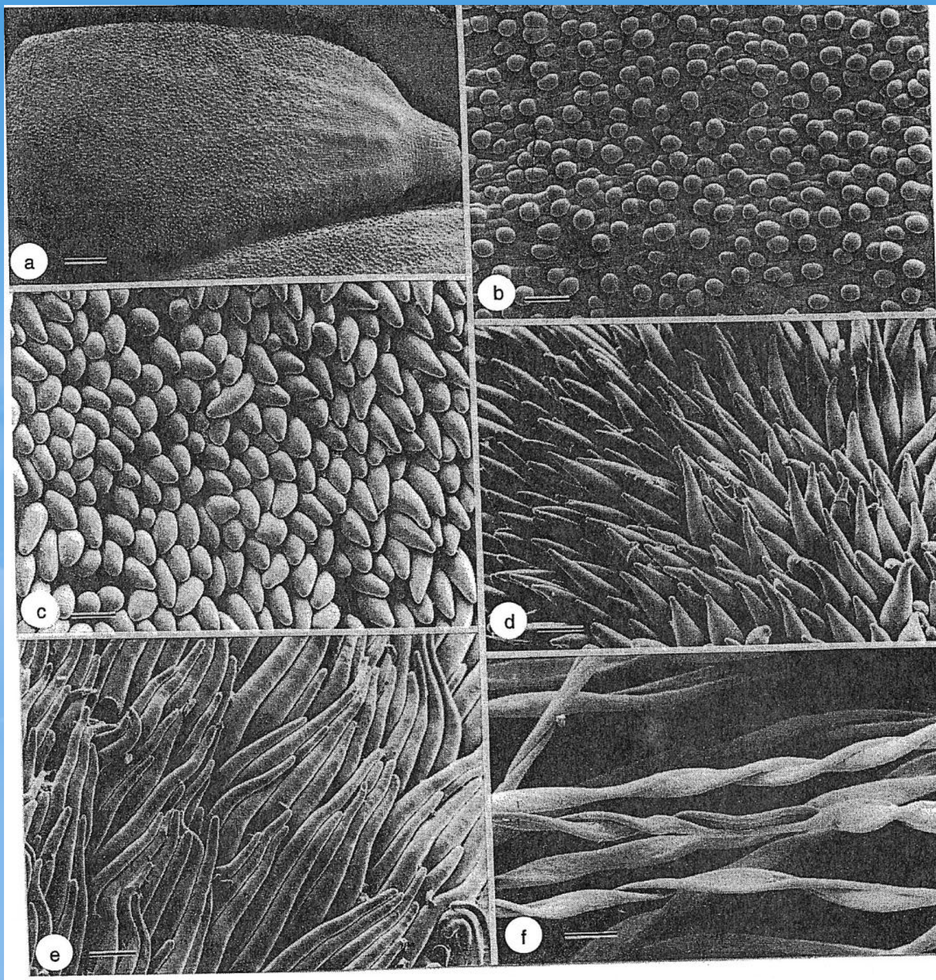


Figure 2.1.21. Fiber development. (*a*) Cotton ovule on the day of anthesis. (*b*) Fiber initials (primordia) on the day of anthesis. (*c*) Developing cotton fibers early on the day after anthesis (+1dpa). (*d*) Developing cotton fibers late on the day after anthesis (+1dpa) (*e*) Developing cotton fibers 3 days after white flower (+3dpa). (*f*) Mature cotton fibers (approximately +48 dpa). Scale bar = approximately 200 μm in (*a*), approximately 30 μm in (*b–f*).

- Lint fiber elongation continues for about 20 days eventually resulting in individual cells which range in length from 25 to 35 mm, depending on genotype and environment.
- The cell wall which is deposited durmg elongation growth is termed the primary cell wall, and it consists of pectin, callose, a thin layer of cellulose, and a cuticle on the surface .

Stewart, 1975;Oosterhuis and Jernstedt (1999)

Fiber

- Around 15-20 days after fiber initiation, deposition of the mainly cellulosic secondary cell wall begins
- Thus in a population of fibers, as well as perhaps in individual fiber cells, elongation and secondary cell wall deposition overlap.
- Secondary cell wall deposition fibers assume a twisted ribbon-like shape

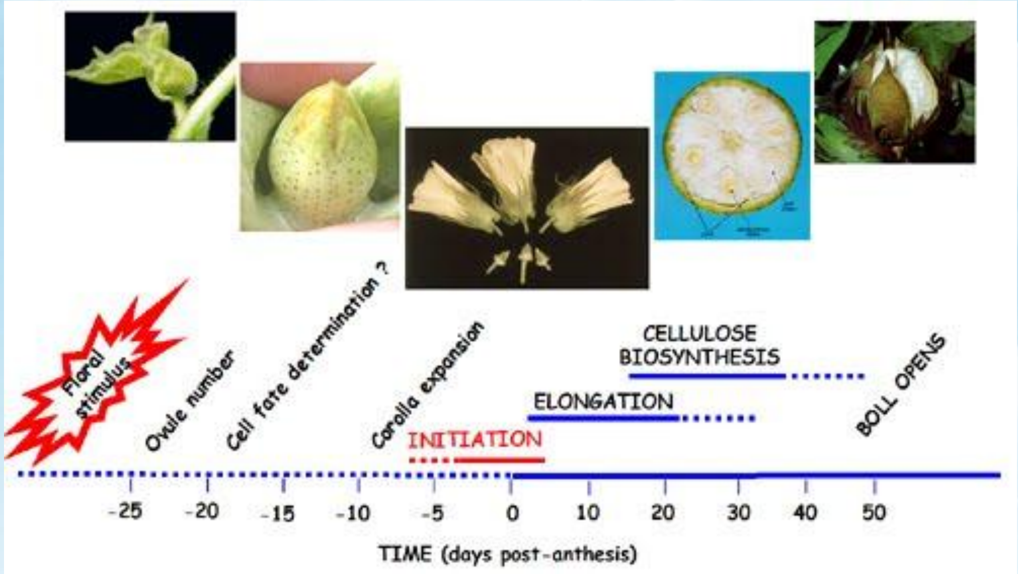


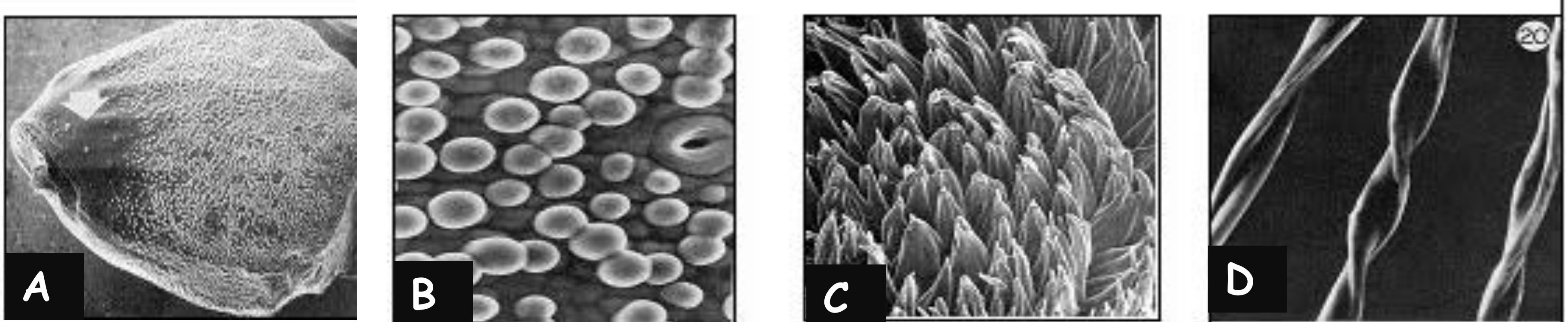
fig: Image: development of cotton fiber (source: http://cottongenomics.biosci.utexas.edu/introduction/cottonfiber.php)

Stewart, 1975;Oosterhuis and Jernstedt (1999)

Fiber

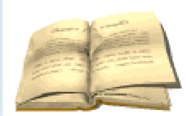
Electron Microscopy Images of Developing Fibers :

A. Fiber initials beginning the process of differentiation.
B. Fiber initials on the day of anthesis,
C. Developing fibers,
D. Fibers at maturity,



http://www.eeob.iastate.edu/faculty/WendelJ/geneexpression.htm

REFERENCES



Poehlman, J.M. and Sleper, D.A. (1995) Breeding Cotton. Breeding Field Crops Fourth Edition , Iowa State University Press/Ames, SB 185.7.P63, p 369-387.

Oosterhuis D.M. And Jornstedth (1999) Mofphology and Anatomyof Cotton Plant. Cotton: Origin, History, Technology, and Production, edited by Wayne C. Smith ISBN 0-471-18045-9 © 1999 John Wiley & Sons, Inc.

Chaudry, M.R. and Guitchounts,A. (2003) Cotton Facts. Technical Paper No.25 of the Common Fund for Commodities, International Cotton Advisory Committe, ISBN 0-9704918-3-2, 158 p.

Barut, A. 2004. Türkiye'de Uygulanmakta Olan Pamuk Islah Metotları, Bitki Islahı Kursu Notları, Nazilli Pamuk Araştırma Enstitüsü Müdürlüğü, 12-16.07.2004, Nazilli/Aydın, 23s.

Ekşi, I. 2004. Pamuğun Taksonomik, Morfolojik ve Agronomik Özelliklerinin Tanıtılması ve Islah Yönüyle Değerlendirilmesi, Bitki Islahı Kursu Notları ppt (38 s), Nazilli Pamuk Araştırma Enstitüsü Müdürlüğü, 12-16.07.2004, Nazilli/Aydın.

Bio 357 Family Malvaceae, Plant Systematics (2008) (by Erin Sanderson) http://www.malvaceae.info/Genera/Hibiscus/galleryL.html

Wendel, J. F., Brubaker, C. Alverez, I. Cronn, R. And Stewart, J. McD. (2009) Evolution and Natural History of the Cotton Genus. Genetics and Genomics of Cotton, Plant Genetics and Genomics: Crops and Models, Volume 3, (Ed. by Andrew H. Paterson) DOI 10.1007/978-0-387-70810-2_1, Springer ScienceBusiness Media, LLC 2009, p 3-22.

Kulkarni V. N., Khadi,B. M., Maralappanavar,M.S., Deshapande, L.A.and Narayanan, S. S. (2009) The Worldwide Gene Pools of Gossypium arboreum L. and G. herbaceum L., and Their Improvement. Genetics and Genomics of Cotton, Plant Genetics and Genomics: Crops and Models, Volume 3, (Ed. by Andrew H. Paterson) DOI 10.1007/978-0-387-70810-2_1, Springer ScienceBusiness Media, LLC 2009, p 69-97.

THANKS