Chapter 1

Cotton: The Crop and Plant

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Cotton as a Crop

Cotton (*Gossypium* spp.) is a unique and intriguing plant. In nature, it is a woody, perennial, semiarid shrub, often reaching the size of a small tree. No cottons are "true" annuals. Some can grow, fruit, and partially mature that fruit within the frost-free portion of a growing season in the temperate zones. Such cottons are referred to as "annuals." Because cotton developed over time under very dry conditions, it has the capacity to compensate for considerable drouth (and other) stress. Because it is in reality a perennial, its basic response to stress is survival. In contrast, annual plants under stress tend to reproduce. For thousands of years, man has sought to improve cotton by developing new varieties, by improved fertility and other cultural practices, and by weed, insect, and disease control. However, the fact remains that, in the temperate zones especially, man is taking a perennial plant ad forcing it to behave as an annual within short-season production. Cotton can be very responsive to management inputs. For example, although the plant is drouth tolerant, irrigation during flowering often increases lint yield and fiber quality. In many situations, timeliness of the management practice is of crucial importance. For example, irrigation too soon before flowering or too late after drouth stress begins can delay maturity of the fiber and reduce yield.

Cotton Crop Production in Oklahoma

Cotton (*G. hirsutum*) is the third leading cash crop in Oklahoma, after "winter wheat" and "all hay," with more than 368,000 acres harvested annually and a worth of more than $74 million to producers (1984-93 statistics). Oklahoma is located on the northern edge of the U.S. Cotton Belt; and producers normally must contend with cool soil temperatures in the spring, the possibility of early fall freezes, and a short growing season between them. Cotton production in Oklahoma is concentrated primarily in the southwestern quarter of the state, a subhumid to semi-arid environment. Dryland production accounts for approximately 77 percent of the total cotton acreage in the state. An intensely irrigated cotton production area occurs within the 47,000-acre Altus/Lugert Irrigation District, located primarily in Jackson County. In this area, cotton is furrow irrigated from lake water feeding through a canal system. Other irrigated areas, often supplied by shallow wells, are either sprinkler or furrow irrigated. Yields under irrigation average more than twice those produced on dryland. Dryland areas normally include cotton as part of a cropping system with wheat, grain sorghum, and/or forages. In some cotton-producing areas of Oklahoma, water and wind erosion are excessive, particularly on coarse-textured soils. Many farmers in those areas have developed specific practices to optimize cotton production yet minimize soil losses.

Oklahoma's climatic conditions, although not as favorable in many ways as are those in the more southern states, do offer some advantages in cotton production. The winters are often sufficiently severe to drastically reduce numbers of overwintering insects compared to warmer areas farther south. This reduces the need for insecticide applications. In some areas, few (if any) applications are required. A number of other factors such as fewer tillage operations including cultivations, less pressure from "hard-to-control" weeds, and once-over stripper harvest also combine to lower the cost of cotton production in Oklahoma compared to most other areas of the Cotton Belt.

Growth and Development of the Cotton Plant

Growth and development of the cotton plant follow a regular pattern with occurrence of roots, leaves, stems, and flowers in an orderly and predictable sequence. Understanding how the cotton plant grows is useful when making management decisions during the season.

Germination

Seed quality is a primary factor influencing germination of cottonseed. The most viable, vigorous planting seed are those that have fully developed embryos, have remained reasonably dry in the field as well as after ginning, and have been stored in a relatively cool, dry place until planted. Moisture content of 10 percent or below is essential for safe seed storage on the farm, even for a short time period.

Under favorable conditions, when a cottonseed germinates in the soil, the embryo enlarges very rapidly. The primary root develops from the radicle, forces its way through the seedcoat at the pointed (micropylar) end, and grows downward into the soil (Figure 1-1). The primary root may reach a depth of 8 to 12 inches prior to seedling emergence. The hypocotyl, the part of the embryo's stem between the primary root and the attachment point of the seedling leaves, elongates rapidly and arches into a "crook" as it pushes its way upward through the soil. The arch protects the tender tissues of the growing point (apex) from abrasion with particles in the soil. The seedcoat is usually left behind in the soil during emergence. The cotton seedling is weak and delicate. Cottonseed should be plant from 1 to 2 inches deep, depending on soil texture and friability at planting

Figure 1-1. Germination of cottonseed.

time. The seed should be in direct contact with moist, firm soil at temperatures of 65 to 70 degrees F or higher.

The Root

The primary root, or taproot, of the cotton plant is continuous with the main stem and grows without branching for several days. Secondary (or side) roots begin to develop about the time the seedling becomes erect and the cotyledons (the seed leaves) expand. The depth to which the primary root ultimately penetrates depends on the depth and character of the various soil layers and upon soil moisture and aeration. In good soils where the aboveground portion of the plant is 8 to 10 inches high, the taproot is 3 to 5 feet deep; however, a taproot 6 to 7 feet deep is not uncommon.

The concentration of the root system in the soil depends on the soil structure and permeability and on the quantity of moisture available. If the plant grows in a soil with little moisture in the upper layers but adequate moisture in deeper ones, the main root system can develop at a considerable depth; when early growth is in fairly wet soil overlaying a compacted layer, the greater part of the functional root system is usually shallow. If the taproot is destroyed, secondary and tertiary roots proliferate to form a lateral root system which does not penetrate the soil as deeply as taproots. Such plants are more subject to moisture stress later in the season. Sixty percent of the water used by the cotton plant comes from the upper 2 feet of the soil; 75 percent comes from the upper 3 feet; and that below 5 to 6 feet is usually lost in the plant.

The Leaf

Leaves of cotton are of three types. The cotyledons are the thick, kidney-shaped, seed leaves. Prophylls are the inconspicuous, first leaves on any branch. "True" leaves are broad, thin, papery, generally hairy, and range from light to dark green. After seedling emergence, the cotyledons turn green upon exposure to light. They manufacture food through photosynthesis in the short term until the true leaves assume that function. The cotyledons are usually shed later in the season. Leaves of most cotton varieties have five more-or-less well defined lobes. Although leaf shape is largely a varietal characteristic, climate and culture can markedly affect leaf development, particularly numbers, thickness, and size. The leaf stalk (petiole) is usually about as long as the leaf blade.

The leaf surface contains many pores (stomata) through which gases are exchanged between the plant (contributes oxygen) and the surrounding atmosphere (contributes carbon dioxide). Most, but not all, of the stomata are on the underside of the leaf.

The cotton plant contains two types of glands, internal and external. The internal glands are visible as black dots generally distributed over the entire aboveground portion of the plant. These glands contain gossypol and play a role in insect suppression. Some varieties without the glands (termed "glandless") are available. The external glands called "nectaries" are found underneath the leaf and inside as well as outside the bracts of the flower. Under the leaf, they're found on the main midrib and occasionally on one or both of the net two largest midribs. These glands produce a sweetish fluid that plays a role in attracting insects. Some varieties without those glands (termed "nectariless") are available.

The Stem

At the lowest node of the cotton main stem, the two cotyledons are attached on opposite sides. Every node above the cotyledons bears a single true leaf. The true leaves develop in a regular spiral arrangement on the main stem, either to the left or to the right. The distance around the stem from one true leaf to the next above or below is normally three-eighths of a complete turn.

The cotton plant has two types of branches, vegetative (monopodial) and fruiting (sympodial) (Figure 2). The main stem is a vegetative branch. Usually, vegetative branches off the main stem occur in a definite zone near the base of the plant, and the fruiting branches occur farther up the stem. Vegetative branches commonly range in number from zero to four. Generally, the more vegetative branches a plant has, the later in maturity it is. Once fruiting branches develop, it is rare for more vegetative branches to be formed. The number of nodes from the base of the main stalk to the first fruiting branch varies considerably among cotton varieties and is affected by plant spacing, nitrogen fertility, moisture, abortion of the terminal bud, and/or lodging of the plant. In most upland cottons, the first fruiting branch develops no lower than the fifth or sixth node above the cotyledons. New fruiting branches are produced by the terminal bud of the main stem at approximately 3-day intervals during the plant's period of active growth.

Figure 1-2. Vegetative and fruiting branches in cotton.

Each vegetative branch of the cotton plant has an almost identical growth pattern. Each develops continuously throughout the growing season from an apical bud at the top of the stem. Some varieties tend more toward lateral growth of the vegetative branches than do others. When growing laterally, vegetative branches are likely to bend over with the weight of maturing bolls and assume an almost horizontal growth. Vegetative branches are straighter and slower growing than fruiting branches. They must rebranch before they can bear flowers and bolls.

Fruiting branches are smaller in diameter, faster growing, and assume a more nearly horizontal attitude than the vegetative branches. The first part of the fruiting branch to become visible is the floral bud (square). As the branch develops, the bud is carried away from the main stem by lengthening of its internode. A leaf develops beside the square, but remains very small until 4 to 7 days after the square becomes visible. As the leaf enlarges and unfolds, the first axillary bud at its base grows out at an angle with its floral bud to form the next internode and flower of the fruiting branch. The resulting development of fruiting branches produces a zigzag appearance in contrast with the straighter vegetative branches.

A mature plant will normally be 2 to 5 feet tall, but can range from 6 inches to over 7 feet. It will be columnar ("cluster" or "semicluster"), pyramidal (Christmas-tree like), or more commonly rounded in shape. Wood in the stem is relatively soft. The bark is moderately thick and tough. The outer layer is more-or-less corky. The bark is greenish to reddish on younger plants, but is yellowish brown on older plants.

The Flower

First encountered in a bud (called a "square") are a whorl of large, conspicuous, green, leafy bracts collectively termed the "involucre." The three bracts, set close together, form an upright triangular structure with the remainder of the floral bud enclosed in its center. Immediately inside the bracts is the true calyx, consisting of five short, equally lobed, green sepals fused together to form a tight cup around the broad, lower end of the bud. Inside the calyx are five petals of the corolla. These are separated except at their basal point of attachment, but are wrapped tightly around each other in the bud. Inside the corolla is the staminal column, bearing about 10 double rows of filaments with two-lobed anthers.

The innermost structure is the pistil. The enlarged conical part at its base, called the ovary, consists of three to six carpels (locules). Typically, the ovary contains 8 to 12 ovules (undeveloped seed). These are initiated in two parallel vertical rows along the placenta, the central column where the carpels are joined together. In the cotton flower, the long tip of the pistil (the stigma) is normally composed of fused lobes; the number of lobes corresponds to the number of locks. The style is the column which connects the stigma to the ovary. Flowering begins low on the plant near the main stem. It proceeds spirally upward and outward on the plant.

The open flower in upland cotton is large and showy. Petals are a creamy white to light yellow in color with no petal spot. The petals open on day one, closing at the end of that day never to reopen. Toward the end of day one, the petals assume a pinkish caste; on the second day, they're reddish in color; usually on the third day, they wither and soon fall off the tiny developing boll. Pollen of cotton is large, cream or yellow in color, round with spines, sticky, and relatively heavy. There are about 45,000 pollen grains per flower; each grain remains viable for about 12 hours. Cross-pollination in Oklahoma ranges from near zero to almost 70 percent. It is accomplished by bumblebees, honey bees, solitary bees, and likely other insects, but not by wind.

The cotton boll is usually light green in color, relatively smooth, and has few oil glands. When ripe, it splits along lines where the carpels meet. The moist fiber dries and fluffs into lint in 3 to 4 days. The dried carpel wall is called the "bur". Dried bolls are of three types. The burs of "open" bolls open widely; and with prolonged exposure, locks of seedcotton tend to fall to the ground. "Storm resistant" bolls hold the seedcotton more firmly and lose considerably less to the ground. "Stormproof" bolls clutch the seedcotton firmly in the bur and lose very little to the ground.

The Fiber

Each cotton fiber is formed from an individual cell in the outer cell layer of the seedcoat. First, the lint fiber cell, a thin-walled tubular structure, starts to lengthen the day of, or day after flowering. Fuzz begins lengthening 5 to 6 days later. Lint grows to its full length, usually within the first 18 to 20 days after blooming; and then it is thickened by daily deposition of successive layers of cellulose on its inner surface in a spiral fashion until 3 to 4 days before the boll opens. The center of the fiber cell (the lumen) is never completely filled.

Elongation of lint fibers proceeds slowly the first 5 days or so, then more rapidly for about the next 10 days, and then more slowly again until the fiber reaches its full length. Elongation is completed sooner in short-fibered than in long-fibered cottons. Fiber length is influenced to some extent by environmental factors, particularly by moisture stress, during elongation. Under any given set of environmental conditions, however, relative fiber length is largely a varietal characteristic.

Thickening of fiber walls begins after elongation ceases, requiring 25 to 30 days. Like many other characteristics of lint development, the degree of thickening and the angle or slant of the spirals depend upon variety, conditions affecting growth, and stage of maturity. Fiber strength is a largely varietal characteristic while fiber fineness is largely environmental.

During growth, the lint hair is essentially circular in cross section. When fully elongated, its diameter is approximately constant (except at the bends). It has a slight tapering at the base and a pronounced tapering at the tip. When the boll opens, water is lost; lint cells collapse and die; and the lint hairs assume a flat, twisted, ribbonlike form. Upon drying, mature lint hairs shrink less than 10 percent in length, but about 30 percent in cross section.

The distribution of lint and fuzz fibers on the cottonseed differs among species. In most upland cottons, both lint and fuzz fibers are distributed rather uniformly over the entire seed surface. In Pima, American-Egyptian, and Sea Island cottons (*G. barbadense*), lint covers the entire seed, fuzz forms a tuft at the sharp end, and other parts of the seed surface are either sparsely covered with fine fuzz or are naked.

The amount of lint on a seed varies considerably among varieties. (Seed of some wild species are entirely naked.) When harvested by spindle picker, in most upland cottons 30 percent of lint by weight is considered a low "gin turnout" and 40 percent a very good one. When harvested by stripper, gin turnout is lower depending on type of stripper and whether a bur extractor is used. Without the bur extractor, a gin turnout of 25 to 30 percent is considered good to very good. Cultural conditions can alter gin turnout, but differences among varieties, in general, remain unchanged proportionately. Closeness of ginning or depth of cut at the gin can, of course, alter the lint percentage.

If fiber and/or seed are exposed to the environment for prolonged periods after boll opening, deterioration (or weathering) can occur. It may take place on the stalk, in modules or trailers, or in bales or seed piles exposed to the weather. Losses occur in fiber weight, fiber strength, fiber length, white color, and lint index. Losses in seed weight and germination percentage also occur.

Order and Rate of Development

The cotton plant develops according to a time schedule that is predictable (within limits). Most developmental phases are consistent. Other phases require relatively longer versus shorter periods according to local climate, variety, and method of culture. The schedule can differ considerably between one section of the Cotton Belt and another. In general, the schedule is as described below.

Under highly favorable conditions, a cotton plant will emerge as early as 4 days after planting. Under very poor conditions, it can require up to 3 weeks. Normally, emergence requires 5 to 10 days with probably 7 days being a reasonable average. If an acceptable stand hasn't been attained in 10 days, serious consideration should be given to replanting.

Usually, about 35 to 40 days after seedling emergence, the first square will appear. The development of the square into an open bloom commonly requires 23 to 25 additional days. This period of development is more consistent than the period between emergence and appearance of the first square. The interval between blooms is about 3 days for a given node on one fruiting branch and on the same node of the next higher fruiting branch. Successive nodes on the same fruiting branch require about 6 days.

Development from open bloom to open boll requires between 45 and 55 days for early and midseason blooms. Late-season blooms require 55 to 70 days. Variation is due primarily to temperature. Most rapid development occurs in the warmer part of the season; development can be exceptionally slow with low fall temperatures.

Squares can be shed at almost any age, but most fruiting forms that are shed do so prior to blooming. Most early fruit shed is due to insect damage. Time of shedding is affected by drouth, extremes in temperature, cloudy weather, insect injury, and disease. Shedding in response to injury may occur from 3 to 10 days after the injury actually takes place. Boll shedding usually occurs within 7 days after blooming. This interval also ranges from 3 to 10 days. Bolls older than 10 days are seldom shed except when the plant is subjected to extreme shock such as harvest-aid chemical treatment, severe water stress, boll weevil or bollworm attack, or frost.

In a boll that requires 50 days to mature (from open bloom to open boll), the approximate periods required for full development of individual properties are as provided in table 1 below.

Table 1-1. Developmental periods for selected boll, seed, and fiber properties after open bloom.

Properties	Days
Boll length	24
Boll weight	45
Seed length	18
Seed dry weight	45
Oil percentage of seed	42

Protein percentage of seed	45
Fiber length	18-20
Fiber strength	43-47
Fiber fineness (micronaire)	43-47

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