COTTON

From Field to Fabric

Cotton remains the most miraculous fiber under the sun. Even after 8,000 years, no other fiber comes close to duplicating all of the desirable characteristics combined in cotton. The fiber of a thousand faces and almost as many uses, cotton is noted for its versatility, appearance, performance, and above all, its natural comfort. From all types of apparel, including astronauts' in-flight space suits, to sheets and towels, and tarpaulins and tents, cotton in today's fast-moving world is still nature's wonder fiber.

Cotton provides thousands of useful products and supports millions of jobs as it moves from field to fabric.

ECONOMICS OF COTTON

Today's modern cotton production system provides significant benefits to rural America's economy and environment. Healthy rural economies are based on stable farm income. Cotton is a vital component to many rural economies in the United States. A bale of cotton weighs about 500 pounds and approximately 73% of the lint goes into making apparel, 18% into home furnishings, and 8% into industrial products[5]. Approximately two-thirds of the harvested cotton crop is composed of the seed, which are crushed to separate its three products–oil, meal, and hulls. Goods made from these include cottonseed oil for cooking; cottonseed meal, a high protein supplement for livestock and poultry; hulls, a roughage for livestock feed; and linters, a cellulose feed stock for many industrial and consumer products.

After processing, the oil is used in many food applications: in salad dressings and mayonnaise, sauces and marinades. As a cooking oil, it is used for frying, commercially and at home. As a shortening or margarine, it is ideal for baked goods and cake icings[3]. Cottonseed oil imparts virtually no taste into foods cooked in it and about 40% of it is used in the US snack food industry. In addition to their use as a livestock feed ingredient, the meal and hulls are sometimes used as organic matter. Average US cottonseed production is about 5 million tons[4] with an estimated market value of over $1 billion[1] and represents about 10-15% of the US cotton industry[2]. The average US crop, moving from the field through cotton gins, warehouses, oil seed mills and textile mills,

to the consumer, accounts for more than $75 billion[4] in products and services. This makes cotton America's number one value added crop. This injection of spending is a vital element in the health of rural economies in the 17 major cotton-producing states from Virginia to California. The gross dollar value of cotton and its extensive system of production, harvesting, and ginning provides countless jobs for mechanics, distributors of farm machinery, consultants, crop processors, and people in support services. Other allied industries such as banking, transportation, warehousing, and merchandising also benefit from a viable US cotton production system. The US produces nearly 15 million bales of cotton annually[1] and is valued at over $5 billion[1]. The farm value of US cotton and cottonseed production is nearly $6 billion[1]. Approximately 69%[4] of cotton produced in the US is exported and this accounts for nearly 30%[4] of world cotton exports.

CROP PRODUCTION

The seventeen cotton-growing states making up the US Cotton Belt span the southern half of the nation from California to Virginia. Cotton's growing season of approximately 140 days is the longest of any annually planted crop in the country. Since there is much variation in climate and soil, production practices differ from region to region. In the western states, for example, nearly the entire crop is irrigated. Planting begins in February in south Texas and as late as June in northern areas of the Cotton Belt. In Georgia, planting takes place from April to early June. Land preparation actually starts in the fall, shortly after harvest. Stalks from the old crop are shredded to reduce food supplies for over-wintering pests. Usually, this residue is left on the surface to protect the soil from erosion. The use of heavy mechanical harvesters compacts the soil, sometimes requiring tillage to loosen the soil for the next crop's roots.

PLANTING

Planting is accomplished with 6, 8, 10, or 12-row precision planters that place the seed at a uniform depth and interval. Young cotton seedlings emerge from the soil within a week or two after planting, depending on temperature and moisture conditions. Squares, or flower buds, form a month to six weeks later and creamy to dark yellow blossoms appear in another three weeks. Pollen from the flower's stamen is carried to the stigma, thus pollinating the ovary. Over the next three days, the blossoms gradually turn pink and then dark red before falling off, leaving the tiny fertile ovary attached to the plant. It ripens and enlarges into a pod called a cotton boll. Individual cells on the surface of seeds start to elongate the day the red flower falls off (abscission), reaching a final length of over one inch during the first month after abscission. The fibers thicken for the next month, forming a hollow cotton fiber inside the watery boll. Bolls open 50 to 70 days after bloom, letting air into space to dry the white, clean fiber and fluff it for harvest.

WEED CONTROL

Cotton grows slowly in the spring and can be shaded out easily by weeds. If weeds begin to overpower the seedling cotton, drastic reductions in yield can result. About 6 to 8 weeks into the season, cotton leaves fully shade the ground and suppress mid-to-late season weeds. Until that time, producers must focus on keeping their fields weed free.

INSECT MANAGEMENT

The cotton plant has evolved with numerous damaging insects. These insects, if left unattended, would virtually eliminate the harvestable crop in most cotton-producing areas. Plants infested with leaf-feeding insects are able to compensate somewhat by producing more leaves. Many of cotton's insects, however, feed on squares and bolls. This reduces the yield and leads to delays in crop development, often into the frost or rainy season. The cotton industry utilizes a multifaceted approach to the problem of insects. Known as Integrated Pest Management (IPM), it keeps pests below yield-damaging levels. IPM is dependent on natural populations of beneficial insects to suppress damaging pests. Additionally, some cotton varieties are genetically bred to be less attractive to insects. Some plants are improved by modern biotechnology, which causes the plant to be resistant to certain damaging worms. Other modern biocontrol strategies are also used. For example, where populations of damaging pink bollworm insects break out, sterile insect releases are used to target the pest and minimize disruption to the beneficial insects. Also, cultural practices that promote earliness and short-season production reduce the vulnerability of cotton production to pests. All plant protection methods and materials used on cotton in the US are thoroughly evaluated by the Environmental Protection Agency (EPA) to assure food safety and protection to humans, animals, and the environment. Pesticide standards for cotton are the same as any other US food crop.

PLANT DISEASES

Cotton diseases have been contained largely through the use of resistant cotton varieties. Rotation to non-host crops, such as grain or corn, also breaks the disease cycle. Nematodes, while not truly a disease, cause the plant to exhibit disease-like symptoms. Nematodes are microscopic, worm-like organisms that attack cotton's roots, causing the plant to stop growing, and resulting in reduced yield. Crop rotation and variety selection are the primary methods of managing nematodes.

SOIL CONSERVATION

Cotton producers expend extra efforts to minimize soil erosion. Cotton is sensitive to wind-blown soil because the plant's growing point is perched on a delicate stem, which is easily damaged by abrasion from wind-blown soil. For that reason, many farmers use minimum tillage practices which leave plant residue on the soil surface, thereby minimizing wind and water erosion. Conservation tillage, the practice of covering the soil in crop residue year-round, is common in windy areas. A growing number of producers also are moving to minimum tillage, or a no-till system to reduce soil movement. In the rain belt, land terracing and contour tillage are standard practices on sloping land to prevent the washing away of valuable topsoil.

IRRIGATION

The cotton plant's root system is very efficient at seeking moisture and nutrients from the soil. From an economic standpoint, cotton's water use efficiency allows cotton to generate more revenue per gallon of water than any other major field crop. Most of the US cotton acreage is grown only on rain moisture. A trend toward supplemental irrigation to carry a field through drought has resulted in increased acreage and helped stabilize yields. Cotton's peak need for water occurs during the ripening of bolls. A limited supply of irrigation water is stretched over many acres via the use of highly efficient irrigation methods such as low energy, precision applications, sprinklers, surge irrigation, and drip irrigation. Not only has irrigation stabilized yields for many growers, it also has allowed production in the dryer states such as California, Arizona, and New Mexico.

HARVESTING

While harvesting is one of the final steps in the production of cotton crops, it is one

of the most important. The crop must be harvested before weather can damage or completely ruin its quality and reduce yield. Cotton is machine harvested in the US, beginning in July in south Texas and in October in more northern areas of the Belt. In Georgia, harvest usually begins in September. In Georgia and most of the Cotton Belt states, spindle harvesters are used. They pull the cotton from the open bolls using revolving, barbed spindles that entwine the fiber and release it after it has separated from the boll. Stripper harvesters, used chiefly in Texas and Oklahoma, have rollers, or mechanical brushes, that remove the entire boll from the plant.

SEED COTTON STORAGE

Once harvested, seed cotton (with the seed still in the lint) must be removed from the harvester and stored before it is delivered to the gin. Seed cotton is removed from the harvester and placed in modules, relatively compact units. A cotton module, shaped like a giant bread loaf, usually contains about fifteen bales. Newer round modules usually contain about four bales of cotton.

GINNING

From the field, seed cotton moves to nearby gins for separation of lint and seed. The cotton first goes through dryers to reduce moisture content, and then through cleaning equipment to remove foreign matter. The cotton is conveyed by air to gin stands, where revolving circular saws pull the lint through closely spaced ribs that prevent the seed from passing through. The lint is removed from the saw teeth by air blasts or rotating brushes, and then is compressed into bales weighing approximately 500 pounds. Baled cotton is moved to a warehouse for storage until it is shipped to a textile mill for use. A typical gin will process about 35-40 bales per hour, while some of today's more modern gins may process as many as 60 bales an hour.

CLASSING

Different cotton varieties yield different attributes. After the lint is baled at the gin, samples taken from each bale are classed according to fiber strength, length, uniformity, color, non-fiber content, and fineness using high volume instrumentation (HVI) and the aid of an expert called a Classer. Scientific quality control checks are made periodically to ensure that instrument and Classer accuracy is maintained. The fiber's fineness is a factor for determining the type of yarns that can be made from the fiber—the finer the cotton fibers, the finer the yarns. Color or brightness of the fibers is also graded. Cotton that is very white generally is of higher value than cottons whose color may have yellowed with exposure to elements before harvesting. Cotton, being a biological product, typically contains particles of cotton leaves called trash. The amount of trash influences the cotton's value since the textile mill must remove trash before processing. The fiber's strength is a measurement that ultimately influences the fabrics made from these fibers. The US Department of Agriculture (USDA) establishes classing standards in cooperation with the entire cotton industry.

MARKETING

Cotton is ready for sale after instrument classing establishes the quality parameters for each bale. The marketing of cotton is a complex operation that includes all transactions involving buying, selling, or reselling, from the time the cotton is ginned until it reaches the textile mill. Growers usually sell their cotton to a local buyer, or merchant, after it has been ginned and baled. If they decide not to sell immediately, they can store it and borrow money against it. Since it is a non-perishable crop, cotton stored in a government-approved warehouse provides a secure basis for a monetary loan.

COTTONSEED

Cotton actually is two crops, fiber and seed. Approximately 10-15% of the farmer's revenue generated by cotton comes from cottonseed. About one-forth of the cottonseed produced from a typical crop is crushed for oil and meal used in food products and in livestock and poultry feed. For each 100 pounds of fiber produced by the cotton plant, it also produces about 115 pounds of cottonseed. Less than 5 percent of the total seed crop is reserved for planting; the remainder is used for feed or as whole seeds or raw material for the cottonseed processing industry. After being separated from the lint at the gin, cottonseeds are transported to a cottonseed crushing mill. There it is cleaned and conveyed to delinting machines which, operating on the same principle as ginning, remove the remaining short fibers, which are known as linters. The linters go through additional processing steps before being made into a wide variety of products ranging from mattress stuffing, computer screens, and paper money. After the linters are removed, the seeds are put through a machine that employs a series of knives to loosen the hulls from the kernel. The seeds are then passed through shakers and beaters. The separated hulls are marketed for livestock feed or industrial products, and the kernels are ready for the extraction of oil, the seeds' most valuable product. Solvent extraction or presses remove the oil. After further processing, the oil is used in cooking oil, shortening, and margarine. Limited quantities also go into soaps, pharmaceuticals, cosmetics, textile finishes, and other products. The remaining meat of the kernel is converted into meal, the second most valuable product. High in protein, it is used in feed for all classes of livestock and poultry. Cottonseed meal makes an excellent natural fertilizer for lawns, flower beds, and gardens.

YARN PRODUCTION

Modernization efforts have brought major changes to the US textile industry. Equipment has been streamlined and many operations have been fully automated with computers. Machine speeds have greatly increased. At most mills, the opening of cotton bales is fully automated. Lint from several bales is mixed and blended together to provide a uniform blend of fiber properties. To ensure that the new highspeed automated feeding equipment performs at peak efficiency and that fiber properties are consistent, computers group the bales for production according to fiber properties. The blended lint is blown by air from the feeder through chutes to cleaning and carding machines that separate and align the fibers into a thin web. Carding machines can process cotton in excess of 100 pounds per hour. The web of fibers at the front of the card is then drawn through a funnel-shaped device called a trumpet, providing a soft, rope-like strand called a sliver (sounds like: driver). As many as eight strands of sliver are blended together in the drawing process. Drawing speeds have increased tremendously over the past few years and now can exceed 1,500 feet per minute. Roving frames draw, or draft, the sliver out even more thinly and add a gentle twist as the first step in ring spinning of yarn. Ring spinning machines further draw the roving and add twist making it tighter and thinner until it reaches the yarn thickness or "count" needed for weaving or knitting fabric. The yarns can be twisted many times per inch. Ring spinning frames continue to play a role in this country, but open-end spinning, with rotors that can spin five to six times as fast, are becoming more widespread. In open-end spinning, yarn is produced directly from sliver, eliminating the roving process. Other spinning systems have also eliminated the need for roving, as well as addressing the key limitation of both ring and open-end spinning, which is mechanical twisting. These systems, air jet and Vortex, use compressed air currents to stabilize the yarn. By removing the mechanical twisting methods, air jet and Vortex are faster and more productive than any other short-staple spinning system. After spinning, the yarns are tightly wound around bobbins or tubes and are ready for fabric forming.

WOVEN FABRICS

Cotton fabric manufacturing starts with the preparation of the yarn for weaving or knitting. Weaving is the oldest method of making yarn into fabric. While modern methods are more complex and much faster, the basic principle of interlacing yarns remains unchanged. On the loom, lengthwise yarns, called the warp, form the skeleton of the fabric. They usually require a higher degree of twist than the filling yarns that are interlaced width wise. Traditionally, cloth was woven by a wooden shuttle that moved horizontally back and forth across the loom, interlacing the filling yarn with the horizontal, length-wise warp yarn. Modern mills use high-speed shuttleless weaving machines that perform at incredible rates and produce an endless variety of fabrics. Some carry the filling yarns across the loom at rates in excess of 2,000 meters per minute. The weaving machines have metal arms, or rapiers, that pick up the filling thread and carry it halfway across the loom where another rapier picks it up and pulls it the rest of the way. Other types employ small projectiles that pick up the filling thread and carry it all the way across the loom. Still others employ compressed air to insert the filling yarn across the warp. In addition to speed and versatility, another advantage of these modern weaving machines is their relatively quiet operation. There are three basic weaves with numerous variations, and cotton can be used in all of them. The plain weave, in which the filling is alternately passed over one warp yarn and under the next, is used for gingham, percales, chambray, batistes, and many other fabrics. The twill weave, in which the yarns are interlaced to form diagonal ridges across the fabric, is used for sturdy fabrics like denim, gabardine, herringbone, and ticking. The satin weave, the least common of the three, produces a smooth fabric with high sheen. Used for cotton sateen, it is produced with fewer yarn interlacings and with either the warp or filling yarns dominating the “face” of the cloth. In some mills, optical scanners continuously monitor fabric production, looking for flaws as the cloth emerges from the weave machine. When imperfections appear, computers immediately print out the location of the flaw so that it can be removed later during fabric inspection.

KNITTED FABRICS

Knitting is a method of constructing fabric by using a series of needles to interlock loops of yarn. Lengthwise rows of these loops, comparable to the warp yarn in woven goods, are called wales. Crosswise rows, comparable to filling yarns, are known as courses. There are numerous similarities in knitting done by hand and machine, but there are also some marked differences. Most cotton is knit on circular machines which have needles fixed to the rim of a rotating cylinder. As the cylinder turns, the needles work their way from stitch to stitch producing a tubular fabric. Its width is regulated by the size of the cylinder, which usually ranges from 9 to 60 inches in diameter. A hand knitter uses two needles forming one stitch at a time. Depending on the width of fabric desired, a modern knitting machine might use over 2,500 needles. Instead of a single cone of yarn, a knitting machine may have up to four cones per inch of fabric width. For example, a machine with a 32-inch cylinder can have over 2,700 needles and 128 cones of yarn feeding simultaneously. These are typical statistics for a machine used in making underwear knits, but figures vary according to the type of machine used and the fabrics produced. A flat knitting machine makes over one million stitches a minute, and can be set to drop or add stitches automatically in order to narrow or widen the fabric at certain points to conform to specific shapes. Knitting machines can be programmed to produce a wide variety of fabrics and shapes.

FABRICS

Cotton fabrics, as they come from the loom in their rough, unfinished stages, are known as greige goods (pronounced: gray goods). Most undergo various finishing processes to meet specific end-use requirements. Some mills, in addition to spinning and weaving, also dye or print their fabrics and finish them. Others sell greige goods to converters who have the cloth finished in independent mills. Finishing processes are numerous and complex, reflecting today's tremendous range and combination of colors, textures, and special qualities. In its simplest form, finishing includes cleaning and preparing the cloth, dyeing or printing it, and then treating it to enhance performance characteristics. To produce a smooth surface in preparation for dyeing and finishing, the greige goods are passed rapidly over gas-fired jets or heated copper plates to singe off lint and loose threads. Moving at speeds that can be greater than 200 yards a minute, the material is scoured and bleached in a continuous process that involves the use of hydrogen peroxide. The time for the chemicals to do the preparation reactions occurs from piling the fabric on conveyor belts that pass through steaming chambers, or stacking in large steam-heated, J-shaped boxes before the goods are withdrawn from the bottom. If a more lustrous cloth is desired, the goods are immersed under tension in a caustic soda solution and then later neutralized. The process, called mercerizing, causes the fiber to swell permanently. This gives the fabric a silken sheen, improves its strength and increases its affinity for dye. Mercerizing also can be done at the yarn stage.

DYEING

The most commonly used processes for imparting color to cotton are piece dyeing and yarn dyeing. In piece dyeing, which is used primarily for fabrics that are to be a solid color, a continuous length of dry cloth is passed full-width through a trough of hot dye solution. The cloth then goes between padded rollers that squeeze in the color evenly and removes the excess liquid. In one variation of this basic method, the fabric, in a rope-like coil, is processed on a reel that passes in and out of a dye beck or vat. Yarn dyeing, which occurs before the cloth is woven or knitted, is used to produce gingham checks, plaids, woven stripes, and other special effects. Blue dyed warp yarns, for example, are combined with white filling yarns in denim construction. One of the most commonly used yarn dyeing methods is package dyeing. In this system, yarn is wound on perforated cylinders or packages and placed on vertical spindles in a round dyeing machine. Dye solution is forced alternately from the outside of the packages inward and from the inside out under pressure. Computers are used increasingly in dyeing processes to formulate and match colors with greater speed and accuracy.

PRINTING

Printing colored designs on cotton cloth is similar to printing on paper. Long runs of the same fabric design are produced on a roller print machine operating at speeds between 50 to 100 yards a minute. As many as 10 different colors can be printed in one continuous operation. A typical printing machine has a large padded drum or cylinder, which is surrounded by a series of copper rollers, each with its own dye trough and doctor blade that scrapes away excess dye. The number of rollers varies according to the fabric design since each color in the design is etched on a separate roller. As the cloth moves between the rotating drum and rollers under great pressure, it picks up color from the engraved area of each roller in sequence. The printed cloth is dried immediately and conveyed to an oven that sets the dye. Automatic screen-printing is another principal method for imparting colored designs to cotton fabrics. Although slower than roller printing, it has the advantage of producing much larger and more intricate designs, elaborate shadings, and various handcrafted effects. In flat bed screen-printing, the fabric design is reproduced on fine mesh screens, one for each color. On each screen, the areas in the design that are not to be penetrated by the dye are covered with lacquer or some other dye-resistant coating. The screens are coated with dye on the back and mounted in the proper sequence above a flat bed. As a belt carries the fabric along from screen to screen, a squeegee or roller presses the dye through the open area of the screen onto the fabric. The new flat bed machines can have speeds of up to 1,200 yards per hour for a fabric with a 36-inch design repeat. Faster by far are the recently developed rotary screen-printing machines, with production speeds of up to 3,500 yards an hour. The system combines roller and screen printing, utilizing perforated cylinders instead of flat screens. The color paste is fed inside the cylinders and a small metal roller forces the color through the pores of the cylinder onto the fabric, which is moving continuously under the cylinders. As many as 16 colors can be printed on one fabric using this method. Use of this technique is increasing since the screens or cylinders can be produced less expensively than the engraved copper rollers used in roller printing.

FINISHING

Finishing, as the term implies, is the final step in fabric production. Hundreds of finishes can be applied to textiles, and the methods of application are as varied as the finishes. Cotton fabrics are probably finished in different ways than any other type of fabrics. Some finishes change the look and feel of the cotton fabric, while others add special characteristics such as durable press, water repellency, flame resistance, shrinkage control, and others. Several different finishes may be applied to a single fabric.

MAJOR USES FOR COTTON

Cotton's competitive share of textile end uses presently stands at approximately 53%[5]. Clothing is the major use for cotton in the US with approximately 80% of cotton's end use being in

the apparel markets. Cotton's share of the retail apparel and home furnishings markets has grown from a historic low of 34% in the early 1970s to more than 50%[5] of each market today. Cotton is used for virtually every type of clothing, from coats and jackets to foundation garments. Most of its apparel usage, however, is for men and boys' clothing. Cotton supplies over 60%[5] of this market, with jeans, shirts, and underwear as major items. In home furnishings, cotton's uses range from bedspreads to window shades. It is by far the dominant fiber in towels and washcloths, supplying almost 96%[5] of that market. Cotton is popular in sheets and pillowcases, where it holds over 72%[5] of the market. Industrial products containing cotton are very diverse and include medical supplies, industrial threads, bookbindings, zipper tapes, and tarpaulins.

1. USDA ten year average of 2006-2015
2. National Cottonseed Products Association publication: "Twenty Facts about Cottonseed"
3. 2016 Cotton Counts its Trade, NCC
4. World of Cotton webpage, NCC August 2016
5. Cotton Incorporated, August 2016

Georgia Cotton Commission
PO Box 1464 • 401 Larry Walker Parkway, Suite A
Perry, Georgia 31069
Phone: 478.988.4235 • Fax: 478.988.4273
www.georgiacottoncommission.org