Chapter 2

TRENDS IN COTTON PRODUCTION: HISTORY, CULTURE, MECHANIZATION AND ECONOMICS

James R. Supak
Texas Agricultural Extension Service
Texas A&M University
Lubbock, Texas
and
Carl G. Anderson
Texas Agricultural Extension Service
Texas A&M University
College Station, Texas
and
William D. Mayfield
USDA, Extension Service
Memphis, Tennessee

INTRODUCTION

Cotton has played an important role in the United States economy for almost 200 years. From the beginning, cotton has been a major cash crop and a significant source of foreign exchange. The invention of the cotton gin encouraged expansion of production and exports of lint to textile mills in England. The development of cotton textile manufacturing in the United States ushered in the industrial revolution and dominated the New England economic scene for many years.

Production regions gradually shifted from east to west, and manufacturing moved from the northeast to the southeast. Cotton, however, remains an economic mainstay crop across the Cotton Belt, where it is produced on farms from Virginia to California. The cotton marketing system moves a large part of the crop long distances to the domestic mills and to ports for export.

The lint is processed into yarns, woven goods and other textile products which are shipped from mills either to manufacturers of cotton apparel and household articles located largely in the industrial northeastern and mid-atlantic states or to foreign manufacturers. Finished cotton items are packaged, stored, and shipped through wholesalers to retail outlets in all cities in the United States and to some foreign outlets. Investments in real estate; processing, marketing and transportation facilities; textile and apparel manufacturing plants; and wholesaling and retailing establishments total billions of dollars.

The industry remains dynamic as continued improvements in technology impacts production units, the market infrastructure, textile equipment, and the market-related services. This makes the cotton industry ever-changing in character.

ORIGIN OF COTTON

Cotton is used in reference to the species of *Gossypium* that produce spinnable fibers (lint) on the seedcoat. The genus *Gossypium* is relatively large, with 39 reported species, and is very diverse (Fryxell, 1984). Today, only four species of *Gossypium* are used in commercial cotton production; two (*Gossypium arboreum* and *Gossypium herbaceium*) are diploids (n = 13) of Middle East or Old World origin and two (*Gossypium barbadense* and *Gossypium hirsutum*) are tetraploids (n = 26) that evolved in the New World.

When and where cotton was first used by man as a raw material for textiles is unknown. Archaeological and historical evidence clearly show that the use of cotton predates recorded history by several centuries (Lewis and Richmond, 1968). Cotton fabrics dating to 3000 B.C. have been found in excavations at Mohenjo-daro in the Indu River Valley in northwestern India (Gulati and Turner, 1928). In the New World, cotton specimens dating to 2500 B.C. were found in the Ancon-Chillon district of Peru (Stephens and Moseley, 1974).

In the Americas, it appears that *Gossypium barbadense* evolved as a wild species in South America and was in fact domesticated in Peru (Lee, 1984). *Gossypium hirsutum* occurs in the wild in Central America, northern South America and in the West Indies. No form of *Gossypium hirsutum* has a history of growing wild as a perennial plant in what is today the continental United States.

Available evidence suggests that Old World cottons were domesticated and cultivated to serve the needs of the ancients in well established, sophisticated agricultural societies that already had the technology for spinning and weaving other fibers (Hutchinson *et al.*, 1947; Lee, 1984). In the Americas, cotton cultivation more than likely evolved from the "dump heap" type agriculture described by Anderson (1954). In such a system, seed and fiber were collected from wild plants by the indigenous people and carried to their dwellings. Later, the discarded seeds provided a convenient source of cotton, and the proximity encouraged cultivation and perhaps selection for plants that produced more lint on the seed, larger bolls, etc. (Lee, 1984).

Botanically, cotton is a perennial of tropical and semi-tropical origins. Through natural crossing and by selection, agronomically acceptable types have evolved which can be grown as day-neutral annuals in temperate zones. In the United States, some cotton is grown close to latitude 37° N; in the Soviet Union, most of the cotton is grown between latitudes 37° N and 42° N; and in northeast China, some cotton is grown north of latitude 40° N. Although cotton is grown commercially in areas with as few as 180 frost-free days (Niles and Feaster, 1984), the major production regions typically have about 200 days between killing frosts and a minimum average summer temperature of 77F (25C) (Starbird *et al.*, 1987). The crop requires more than 160 days when minimum temperatures are above 60F (15C) (Waddle, 1984).

The wild species of *Gossypium* occur in relatively arid parts of the tropics and subtropics (Fryxell, 1979; Fryxell, 1986). For commercial production, however, an acceptable cotton crop requires at least 20 inches (50 cm) of water during the growing season (Waddle, 1984). In the United States, cotton is usually irrigated when annual rainfall is less than 16 inches (40 cm). Supplementary irrigation is frequently used in the 16- to 35-inch (40 to 88 cm) rainfall zone, whereas most of the cotton produced in higher rainfall areas is typically not irrigated. Cotton is adapted for production on a wide range of soil types as long as inherent or supplemental fertility is adequate to sustain desired yield levels and the soil's physical condition allows adequate drainage and root penetration.

COTTON IN THE NEW WORLD

In 1492, when Columbus landed in the New World, he found fabrics that were woven from cotton produced by the native population. The Europeans that followed Columbus found not only cotton culture but also highly skilled spinning and weaving capabilities among the native population in the West Indies, Mexico and Peru (Brooks, 1911). The people were using cotton bedding, clothes, armor, awnings, carpets and tapestries. Cotton was an important item of trade in the Aztec, Maya and Inca civilizations and great quantities were seen in the market places by explorers from Spain (Lewis and Richmond, 1968).

Cotton culture and the use of cotton textiles apparently extended north of the Mexican border into New Mexico, Southern Colorado and Utah in prehistoric times (Kent, 1957). During the Spanish colonial period, however, cotton was found growing only as far north as the modern town of Espanola in the West Indies, the Hopi Indian Country in the Gila River Valley in Arizona, and along the San Pedro and Santa Cruz Rivers in South America. No native cottons were found in the southeastern and mid-south sections of the United States (Lewis and Richmond, 1968), and there is no evidence of the presence of cotton in these areas until after 1600.

COTTON CULTURE AND PRODUCTION IN THE UNITED STATES

COLONIAL PERIOD

> "Plant your cotton when the leaf upon the oak is as big as a Squirrel's ear." (Lyman, 1866)

The first attempts by English colonists to produce cotton in the United States were made in the early 1600s at Jamestown. Settlers were provided seed to determine if the crop could be grown in the newly established colony. Some years before Jamestown was settled, England had acquired the technology to weave cotton-wool blends (Brooks, 1911) and needed a steady supply of cotton at a controllable price to support its textile manufacturing industry.

The first cottons used by the colonists were types of *Gossypium hirsutum*, probably from the Levant region (Brown and Ware, 1958; Niles and Fester, 1984). Quite possibly, these importations were returned New World stocks that had been carried to the Old World by early explorers. Eventually, settlers, traders, travelers and governmental officials brought cottonseed to the United States from Italy , the West Indies, the Caribbean, Egypt, Siam, India and other tropical and semi-tropical climates. Cultivars that were photoperiodic were quickly eliminated because they produced no seed. The stocks that proved to be best adapted to the upland sites were subsequently called upland cottons and were cultivars of *Gossypium hirsutum* (Brown and Ware, 1958). A few Asiatic cultivars were introduced and temporarily established but did not compete in production and quality with the *Gossypium hirsutum* and were soon discarded. Thus, in this early period, stringent selection pressures were applied for plants with a day-neutral habit which facilitated the establishment of near-annual forms that exhibited desired yield and fiber characteristics.

Brooks (1911) describes the cottons that survived in the South Atlantic states as "...a different species...unlike the cotton of the tropics...(with) lint not so fine as that of India...a smaller plant...that requires replanting every year.... But the most difficult thing about this hybrid plant is in the separation of the seed from the lint.... it (lint) adheres so closely to the seed that it cannot be shaken off, whipped off or rolled off, and it is with much difficulty that it can be picked off."

Domestic manufacturing of cotton goods was discouraged and even forbidden to the colonists. Nevertheless, settlers coming from England brought with them knowledge of spinning and weaving, and soon small "cotton patches" were established to supply cotton for domestic needs such as clothing, bedding and home furnishings. Cotton was cultivated, mainly in garden plots, with some success as far north as Delaware, New Jersey, Pennsylvania and Maryland. The more serious efforts to produce cotton occurred in Virginia, the Carolinas and Georgia, but even here plantings rarely exceeded one-to-five acres. Cotton production in Colonial America was not profitable except for home use. Tobacco, indigo and rice developed into the primary cash crops for the early English settlers, and receipts from these crops were used in part to purchase textile products from abroad that could not be manufactured in the colonies.

THE 1775-1792 PERIOD

The lackadaisical attitude of the English colonists to cotton production and manufacturing of textile goods was brought to an abrupt halt when the availability of textiles was curtailed by the Revolutionary War. By the standards of those days, cotton acreage was rapidly expanded to meet domestic fiber needs. However, the production of cloth was severely restricted by the lack of efficient systems to separate the lint from the seed and to process the fiber into cloth.

The immediate effects of the British textile embargo were to stimulate home manufacture of textiles. Large quantities of homespun cloth were produced on home-spinning frames and looms, and a "factory" was built in Philadelphia for cording and spinning cotton. Societies were formed to check on importation of clothes from abroad and to encourage manufacture and use of American goods (Brooks, 1911), much like the modern day "Grown and Made in the USA" movement.

A series of inventions—beginning with the development of the fly shuttle by John Kay in 1738—propelled British textile manufacturing from a fragmented, home-based, labor intensive industry to a concentrated, highly mechanized factory system (Anderson, 1976; Baines, 1845; Lee, 1984; Dodge, 1984). The fly shuttle was followed by James Hargreaves "spinning jenny" in the 1760s. Also during this period, Richard Arkwright directed the development of a successful spinning frame that employed roller drafting and the flyer bobbin principle and which was adapted to water power. In the mid-1770s, Samuel Crampton developed the "spinning mule" which combined the spinning jenny and the spinning frame and, in time, replaced both machines (Catling, 1970).

The perfection of the steam engine by James Watt in 1790 provided a power source for the mechanization of the spinning mules and spinning frames. Around 1792, steam was used to power the loom developed by Edmund Cartwright. The first mills appeared in England in the 1740s. By the 1780s England had 120 mills and several more had been built in other countries. As the 19th century began, powered mules and spinning frames as well as powered, all-metal looms were the standard tools of the rapidly expanding textile industry in England.

Once the War of Independence had been won, the newly formed United States strove for unification under the Constitution and for self-sufficiency in both agriculture and manufacturing. Political matters such as states rights, slavery and protective tariffs had not as yet become regionalized issues. The demand for cotton and cotton textiles triggered by the Industrial Revolution seemed boundless. England's burgeoning textile industry required substantially more raw cotton than could be provided by the production regions of India, the Mediterranean areas, the West Indies and the countries of South America.

American planters in the southern states desperately needed a cash crop and were eager to supply the English cotton market. Production expanded from the coastal areas into the interior regions of the Carolinas and Georgia. Following the French and Indian Wars in early 1760s, the Pennsylvania Dutch, Tidewater people and European immigrants moved into up-country regions. Cotton culture expanded with the spread of the population (Niles and Feaster, 1984).

As noted previously, the upland types of *Gossypium hirsutum* became the predominant cotton grown in the colonies. Two principal types, described as naked black seeded and fuzzy green seeded, gained initial acceptance but the latter became dominant by the late 1700s. Demand for cotton stimulated a search for better adapted, more productive cottons. New sources of seed were frequently tested, and many planters experimented with intra-cultivar selections. A Danish West Indies planter named Von Rohr was commissioned by his government during the 1780s to collect and study cottons obtained from the known production regions of the world. He established the first extensive collection of living material of *Gossypium* in St. Croix and attempted to characterize these plants according to characteristics having agricultural importance (Fryxell, 1979). Rohr also was among the first to begin technical cotton breeding in the New World. In his writings, Rohr reportedly discusses methods he used in selection and hybridization of cotton (Brown, 1927; Watt, 1907). In all likelihood, seed from some of his specimens were eventually carried to the United States.

About 1785, Sea Island cotton, *Gossypium barbadense*, was introduced and soon gained limited acceptance along the coastal areas and islands off the coasts of the Carolinas and Georgia. The Sea Island or "lowland" type had two distinct advantages over the upland types: (a) it produced a superior quality fiber, and (b) the lint could be separated from the seed with roller gins. Its disadvantages were that it failed to mature in inland locations, and its yield potential was well below that of the upland cottons.

The Industrial Revolution was also making its presence felt in America. Whereas an agricultural economy prevailed in the South, the North was developing numerous industrial and trade enterprises. Like the rest of the world, America hungered for the technology to develop its own textile industry. England had the necessary technology but forbade its export. In order to preserve exports of cotton textiles and hopefully keep the United States an agricultural economy, English manufacturers made every effort to keep cotton-mill machinery out of the United States. Although the Revolution had stimulated American household manufacturing of textiles, soon afterwards, British goods were again imported in large quantities (Cohn, 1956).

To establish a mercantile industry, various incentives were offered by American entrepreneurs to inventors and other enterprising individuals to develop the high capacity spinning and weaving equipment needed for a factory system

(Brooks, 1911). In 1789, Samuel Slater, an English cotton-mill mechanic, immigrated to America. With financial backing from two American businessmen, Slater reproduced from memory some of England's most efficient mill machines. Then, he supervised the construction and operation of America's first cotton mills, including the Old Slater Mill which was built in 1793 and still stands in Pawtucket, Rhode Island.

The southernmost states had the soil resources, climate and labor force to grow cotton on millions of idle acres. The agrarian South desperately needed a cash crop and an apparently insatiable market existed for raw cotton abroad. Also, the prospects for a domestic textile industry, centered around the evolving factory system, further stimulated demand for cotton.

Yet, before southern planters could take advantage of these ready markets, the problem of separating the lint from the seed of the green-seeded cottons had to be solved.

1793—THE COTTON GIN

> "After their day's work the good man and his wife and children sitting around the open fireplace...would bring the basket out from under the bed and pick seed until bedtime. Usually a shoe full of lint was a good night's work for any one person. So tedious was the process that it took one man a whole day to pick one pound of lint. ...it would take such a man nearly two years to pick enough lint to make a bale of cotton" (Brooks, 1911).

Before cotton fibers can be used in textile manufacturing, they must be removed from the seed either by hand or by machine. The first recorded machine designed to separate the lint from the seed was a crude version of the modern roller gin. The "churka" gin was first used in India many centuries ago. This type of gin only works with long staple, smooth seeded cottons such as Sea Island, Egyptian or Pima. The output of these manually operated machines was about five pounds of lint per day. According to Brown (1927), attempts were made by Krebs of Mississippi in 1772, Burden of South Carolina in 1777 and Eve of Georgia in 1790 to improve the roller gin and perhaps to even enable it to gin green-seeded cotton; none proved successful.

In 1793, Eli Whitney, a native of Westboro, Massachusetts and newly graduated from Yale, accepted a teaching position in South Carolina. A mis-communication regarding the availability of the position he sought and a chance encounter with the widow of General Nathanial Green introduced young Whitney to plantation life in Georgia, cotton production, the economic plight of the southern farmer and the need for a machine capable of processing upland cotton. Whitney received a patent on a machine to gin cotton on March 14, 1794 (Tompkins, 1901).

Whitney's gin used metal spikes driven into a wooden cylinder in concentric rows to remove cotton fiber from the seed. It was a batch-type process. To operate the gin, a few handfuls of seedcotton were placed in the gin and the cylinder was turned by hand until the fibers were removed from the seed and brushed into a pile behind the machine. The gin was then stopped, the seeds were removed, and the process repeated. Whitney's invention, and the many copies that followed, proceeded almost directly from conception to execution. Within a year, gins were being manufactured and stationed in key production areas.

Henry Ogden Holmes, a plantation blacksmith from South Carolina, invented and received a patent on May 12, 1796, for an improved gin very similar in principle to modern gins. The Holmes gin used metal saws positioned on a shaft rather than spikes in a wooden cylinder. His machine allowed the cleaned seeds to fall out the bottom, making ginning a continuous, rather than a batch process. Whitney soon recognized the value of Holmes' improvements and incorporated the saw teeth in his machines (Bennett, 1961).

THE 1794-1860 PERIOD

> "... and the trespass of a little worm upon it's (cotton's) green leaf is more to England than the advance of the Russian army on her Asian outposts...." Henry W. Grady (Brooks, 1911)

The development of the cotton gin resulted in an immediate, dramatic increase in cotton production in the United States as shown in Table 1 and in the production summary for the cotton producing states provided in Table 2.

In the 40 years following the invention of the cotton gin, production more than doubled during each succeeding decade (Table 2). Also, in 1791, there were five southern states and only two produced enough cotton to warrant mention in production reports of the day. By 1822, Missouri, Louisiana, Mississippi and Alabama joined the Union and quickly became major cotton producing states. The annexation of Arkansas in 1836, and Texas and Florida in 1845 led to additional acreage expansion, and, by the outbreak of the Civil War, the "cottonbelt" states were producing about four million bales annually—more than half the world supply of cotton (Brown, 1927).

During this period, exports and domestic consumption were keeping pace with production increases. In 1790, only 279 bales were exported; in 1800, 31,822; in 1820, 249,787; in 1840, 1,060,408 and in 1859, 3,535,373 bales, Table 1 (Brown, 1927). The great majority of this cotton was being shipped to England, although France and other European nations imported substantial quantities as well. The value of cotton exports reached $191.8 million in 1860 (Cohn, 1956).

In the United States, the first cotton mill was built in Beverly, Massachusetts in 1787. Thereafter, the number of mills constructed, mainly in the New England states, increased steadily. The War of 1812 gave added impetus to domestic manufacturing—and textile mill construction—because United States citizens were again unable to import needed goods from Great Britain.

Table 1. U.S. Cotton: acreage, yield, production, imports, domestic use, exports, carryover and price, 1790-1989.

				Supply				Demand				
Year	Planted acres	Harvested acres	Yield per acre	Beginning carryover	Produc-tion	Imports	Total supply	Mill con-sumption	Exports	Total use	Ending carryover	Season av-erage price
	(1000 acres)		(lb/acre)					(1000 bales)				
1790					3	1		11		11		26.00
1791					4	1				0		29.00
1792					6	6			1	1		32.00
1793					10	5			4	4		33.00
1794					11	9			9	9		36.50
1795					17	9			12	12		36.50
1796					21	7			8	8		34.00
1797					23	8			19	19		39.00
1798					31	8			19	19		44.00
1799					42	9		17	36	53		28.00
1800					73	9		19	32	51		44.00
1801					100				48	48		19.00
1802					115	1			75	75		19.00
1803					126				70	70		20.00
1804					136			23	77	100		23.00
1805					146	1			71	71		22.00
1806					167	1			128	128		21.50
1807					167	6			21	21		19.00
1808					157	2			102	102		16.00
1809					172	1		33	187	220		16.00
1810					178			36	124	160		15.50
1811					167	1			58	58		10.60
1812					157	3			38	38		12.50
1813					157				35	35		15.50
1814					146			52	166	218		21.00
1815					209	2			164	164		29.00
1816					259	3			171	171		27.10
1817					272	4			185	185		31.00
1818					262	5			176	176		24.70
1819					349				256	256		16.50
1820					335			100	250	350		14.90
1821					377				289	289		14.70
1822					439				347	347		11.20
1823					387	1			287	287		14.70
1824					450				353	353		17.90
1825					533				409	409		13.40
1826					732			104	589	693		10.20
1827					565	1		85	421	506		10.30
1828					680			85	530	615		9.90
1829					764			90	597	687		9.70
1830					732			130	554	684		10.10
1831					805			131	644	775		9.10
1832					816			142	649	791		11.40
1833					931			149	769	918		13.10
1834					962	2		167	775	942		16.30
1835					1,062			185	847	1,032		16.70
1836					1,129	1		176	888	1,064		14.40
1837					1,428			195	1,192	1,387		10.00
1838					1,093			222	827	1,049		13.20
1839					1,654			237	1,488	1,725		9.40
1840					1,348	1		245	1,060	1,305		9.60
1841					1,398			222	1,169	1,391		8.10
1842					2,035	2		278	1,585	1,863		7.20
1843					1,750	1		299	1,327	1,626		7.80
1844					2,079	1		338	1,746	2,084		5.90
1845					1,806			363	1,095	1,458		7.80

Table 1. Continued

Year	Planted acres	Harvested acres	Yield per acre	Supply: Beginning carryover	Supply: Production	Supply: Imports	Total supply	Demand: Mill consumption	Demand: Exports	Total use	Ending carryover	Season average price
	(1000 acres)		(lb/acre)					(1000 bales)				
1846					1,604			386	1,054	1,440		10.90
1847					2,128	1		537	1,629	2,166		8.50
1848					2,615			586	2,053	2,639		7.20
1849					1,975			576	1,271	1,847		12.00
1850					2,136			423	1,854	2,277		12.60
1851					2,799	1		617	2,186	2,803		9.30
1852					3,130	1		736	2,223	2,959		11.00
1853					2,766	1		663	1,976	2,639		11.00
1854					2,708	4		642	2,017	2,659		10.30
1855					3,221	2		731	2,703	3,434		10.30
1856					2,874	2		762	2,097	2,859		13.20
1857					3,012			551	2,237	2,788		12.50
1858					3,758			867	2,773	3,640		12.10
1859					4,310			845	3,535	4,380		11.30
1860					3,841			842	615	1,457		12.30
1861					4,491	62		369	10	379		28.20
1862					1,597	68		287	23	310		65.20
1863					449	52		220	24	244		91.20
1864					299	69		344	18	362		95.40
1865					2,094	10		615	1,301	1,916		44.30
1866		7,666	122		2,097	1		715	1,323	2,038		32.20
1867		7,864	143		2,520	0		844	1,511	2,355		24.50
1868		6,973	151		2,366	2		860	1,288	2,148		28.60
1869		7,751	155		3,011	3		797	1,980	2,777		25.30
1870		9,238	208		4,352	2		1,027	2,894	3,921		17.00
1871		8,285	159		2,974	6		1,147	1,851	2,998		21.90
1872		9,580	182		3,933	10		1,116	2,437	3,553		20.20
1873		10,998	168		4,168	4		1,213	2,706	3,919		17.30
1874		10,753	157		3,836	4		1,098	2,523	3,621		15.70
1875		11,348	181		4,631	4		1,256	3,003	4,259		13.10
1876		11,747	168		4,474	5		1,314	2,869	4,183		9.71
1877		12,606	170		4,773	5		1,459	3,198	4,657		8.53
1878		13,539	168		5,074	5		1,457	3,265	4,722		8.16
1879		14,474	181		5,756	8		1,501	3,711	5,212		10.28
1880		15,921	191		6,606	5		1,866	4,409	6,275		9.83
1881		16,483	149		5,456	3		1,849	3,430	5,279		10.66
1882		15,638	209		6,949	5		2,038	4,582	6,620		9.12
1883		16,295	162		5,713	11		1,814	3,745	5,559		9.13
1884		16,849	155		5,682	7		1,687	3,740	5,427		9.19
1885		17,922	170		6,576	8		2,095	4,193	6,288		8.39
1886		18,370	164		6,505	8		2,050	4,274	6,324		8.06
1887		18,793	175		7,047	12		2,205	4,557	6,762		8.55
1888		19,520	170		6,938	15		2,309	4,720	7,029		8.50
1889		20,191	177		7,473	18		2,518	4,934	7,452		8.55
1890		20,937	196		8,653	46		2,604	5,859	8,463		8.59
1891		21,503	199		9,035	64		2,847	5,888	8,735		7.24
1892		18,869	169		6,700	86		2,416	4,456	6,872		8.34
1893		20,256	175		7,493	59		2,300	5,309	7,609		7.00
1894		21,886	219		9,901	99		2,984	7,010	9,994		4.59
1895		19,839	172		7,162	112		2,500	4,710	7,210		7.62
1896		23,230	175		8,533	115		2,841	6,172	9,013		6.66
1897		25,131	209		10,899	106		3,472	7,757	11,229		6.68
1898		24,715	223		11,278	106		3,672	7,662	11,334		5.73
1899		24,163	185		9,346	140		3,687	6,228	9,915		6.98
1900		24,886	195		10,124	109		3,604	6,800	10,404		9.15
1901		27,050	168		9,508	202		4,080	6,949	11,029		7.03
1902		27,561	185		10,630	151		4,187	7,084	11,271		7.60

Table 1. Continued

				Supply				Demand				
Year	Planted acres	Harvested acres	Yield per acre	Beginning carryover	Production	Imports	Total supply	Mill consumption	Exports	Total use	Ending carryover	Season average price
	(1000 acres)		(lb/acre)					(1000 bales)				
1903		27,762	170		9,851	103		3,981	6,207	10,188		10.49
1904		30,077	214		13,438	129		4,523	8,908	13,431		8.98
1905		27,753	182		10,576	144		4,877	7,118	11,995		10.78
1906		31,404	202	1,935	13,274	227		4,974	8,943	13,917	1,349	9.58
1907		30,729	173	1,349	11,106	153		4,493	7,666	12,159	1,515	10.36
1908		31,091	204	1,515	13,241	181		5,092	8,955	14,047	1,236	9.01
1909	31,744	30,555	157	1,236	10,005	170		4,622	6,353	10,975	1,484	13,60
1910	32,480	31,508	176	1,484	11,609	245		4,498	8,027	12,525	1,040	13.95
1911	35,634	34,916	215	1,040	15,694	233		5,129	11,116	16,245	1,375	9,60
1912	33,199	32,557	201	1,375	13,703	249		5,483	9,146	14,629	1,777	11.49
1913	35,721	35,206	192	1,777	14,153	273		5,626	9,508	15,134	1,648	12.51
1914	36,197	35,615	216	1,511	16,112	261	15,775	5,597	8,702	14,299	1,366	7.36
1915	30,544	29,951	179	1,366	11,172	382	17,654	6,398	6,113	12,511	3,936	11.22
1916	33,977	33,071	166	3,936	11,448	438	15,442	6,789	5,525	11,923	3,140	17.33
1917	33,064	32,245	167	3,140	11,284	292	14,796	6,566	4,402	11,191	2,720	27.12
1918	36,123	35,038	164	2,720	12,018	221	14,189	5,766	5,774	12,340	3,450	28.92
1919	34,573	32,906	166	3,450	11,411	202	15,558	6,420	6,707	12,473	4,287	35.41
1920	35,872	34,408	187	4,287	13,429	700	16,313	4,893	5,973	12,393	3,563	15.92
1921	29,716	28,678	133	3,563	7,945	226	17,060	5,910	6,348	11,241	6,534	17.01
1922	32,176	31,361	149	6,534	9,755	363	14,875	6,666	5,007	10,917	2,832	22.87
1923	37,000	35,550	136	2,832	10,140	470	13,031	5,681	5,815	12,481	2,325	28.69
1924	40,690	39,501	165	2,325	13,630	292	12,788	6,193	8,240	13,921	1,556	22.91
1925	45,968	44,386	174	1,556	16,105	313	15,508	6,456	8,267	14,460	1,610	19.59
1926	45,839	44,608	193	1,610	17,798	326	18,059	7,190	11,299	17,775	3,543	12.47
1927	39,471	38,342	162	3,543	12,956	401	12,699	6,834	7,857	15,047	3,762	20.19
1928	43,737	42,434	163	3,762	14,477	338	16,883	7,091	8,419	15,253	2,536	17.99
1929	44,448	43,232	164	2,536	14,825	458	17,291	6,106	7,035	14,126	2,312	16.79
1930	43,329	42,444	157	2,312	13,932	378	17,238	5,263	7,133	13,239	4,530	9.46
1931	39,110	38,704	212	4,530	17,097	108	18,394	4,866	9,193	14,456	6,370	5.66
1932	36,494	35,891	174	6,370	13,003	132	23,131	6,137	8,895	13,761	9,678	6.52
1933	40,248	29,383	213	9,678	13,047	130	22,518	5,700	7,964	14,101	8,165	10.17
1934	27,860	26,866	172	8,165	9,636	148	20,977	5,361	5,037	10,737	7,744	12.36
1935	27,888	27,335	186	7,744	10,638	107	17,323	6,351	6,627	11,628	7,208	11.09
1936	30,932	30,054	198	7,208	12,407	155	17,783	7,950	5,689	12,040	5,409	12.30
1937	34,090	33,623	270	4,499	18,946	159	22,924	5,748	5,976	11,724	11,533	8.70
1938	25,018	24,248	236	11,533	11,943	150	23,268	6,858	3,512	10,370	13,033	8.70
1939	24,683	23,805	238	13,033	11,817	168	24,568	7,784	6,501	14,285	10,564	9.90
1940	24,871	23,861	253	10,564	12,566	193	23,020	9,722	1,174	10,896	12,203	10.80
1941	23,130	22,236	232	22,167	10,744	274	22,959	11,170	1,162	12,332	10,640	17.90
1942	23,302	22,602	272	22,585	12,817	178	23,305	11,100	1,498	12,598	10,657	19.20
1943	21,900	21,610	254	23,570	11,427	135	21,856	9,943	1,146	11,089	10,744	19.60
1944	19,990	19,617	299	25,404	12,230	193	22,858	9,568	1,909	11,477	11,164	20.60
1945	17,588	17,029	253	26,598	9,015	349	20,359	9,163	3,678	12,841	7,326	24.40
1946	18,251	17,584	235	23,041	8,640	284	16,170	10,025	3,656	13,681	2,530	33.30
1947	21,611	21,330	266	17,097	11,860	244	14,416	9,354	2,025	11,379	3,080	32.40
1948	23,264	22,911	311	14,500	14,877	173	17,892	7,795	4,961	12,756	5,287	30.00
1949	27,719	27,439	284	14,600	16,128	254	21,453	8,851	6,004	14,855	6,846	30.30
1950	18,866	17,843	269	6,846	10,014	189	16,914	10,509	4,280	14,789	2,278	41.40
1951	29,353	26,949	269	2,278	15,149	79	17,419	9,196	5,711	14,907	2,789	38.40
1952	28,065	25,921	280	2,789	15,139	195	18,149	9,461	3,181	12,642	5,605	32.50
1953	26,872	24,341	324	5,605	16,438	145	22,149	8,576	3,914	12,490	9,728	32.00
1954	20,052	19,251	341	9,728	13,673	150	23,465	8,841	3,585	12,426	11,205	32.00
1955	17,991	16,928	417	11,205	14,698	137	26,022	9,210	2,320	11,530	14,529	32.10
1956	17,077	15,615	409	14,529	13,290	137	27,986	8,608	7,917	16,525	11,323	30.00
1957	14,310	13,558	388	11,323	10,948	141	22,572	7,999	5,959	13,958	8,737	30.50
1958	12,379	11,849	466	8,737	11,495	137	20,409	8,703	2,895	11,598	8,885	30.80
1959	15,833	15,117	461	8,885	14,527	136	23,628	9,017	7,391	16,408	7,560	28.60

Table 1. Continued

Year	Planted acres	Harvested acres	Yield per acre	Supply: Beginning carryover	Supply: Production	Supply: Imports	Total supply	Demand: Mill consumption	Demand: Exports	Total use	Ending carryover	Season average price
	(1000 acres)		(lb/acre)					(1000 bales)				
1960	16,080	15,309	446	7,501	14,237	129	21,557	8,353	6,857	15,210	7,056	31.50
1961	16,588	15,634	438	7,056	14,283	153	21,206	9,017	5,056	14,073	7,699	34.30
1962	16,293	15,569	457	7,699	14,827	137	22,374	8,484	3,429	11,913	11,136	33.20
1963	14,843	14,212	517	1,136	15,294	135	26,114	8,696	5,775	14,471	12,351	33.60
1964	14,835	14,057	517	2,351	15,145	118	27,151	9,261	4,195	13,456	14,249	31.00
1965	14,152	13,615	527	4,249	14,938	118	28,873	9,596	3,035	12,631	17,028	29.30
1966	10,349	9,552	480	7,028	9,557	105	26,246	9,574	4,832	14,406	12,344	21.70
1967	9,448	7,997	447	2,344	7,443	149	19,513	9,077	4,361	13,438	6,584	26.70
1968	10,912	10,160	516	6,584	10,926	168	17,263	8,332	2,825	11,157	6,544	23.10
1969	11,882	11,055	434	6,544	9,990	52	16,320	8,114	2,878	10,992	5,843	22.00
1970	11,945	11,155	438	5,843	10,192	37	15,873	8,204	3,897	12,101	4,203	22.90
1971	12,355	11,471	438	4,203	10,477	72	14,555	8,259	3,385	11,644	3,258	28.20
1972	14,001	12,984	507	3,258	13,704	34	16,183	7,769	5,305	13,074	4,221	27.30
1973	12,480	11,970	520	4,221	12,974	48	17,176	7,472	6,123	13,595	3,808	44.60
1974	13,679	12,547	441	3,808	11,540	34	15,227	5,860	3,926	9,786	5,708	42.90
1975	9,478	8,796	453	5,708	8,302	92	13,932	7,250	3,311	10,561	3,681	51.30
1976	11,636	10,914	465	3,681	10,581	38	14,151	6,674	4,784	11,458	2,928	64.10
1977	13,680	13,275	520	2,928	14,389	5	17,157	6,483	5,484	11,967	5,347	52.30
1978	13,375	12,400	420	5,347	10,856	4	16,042	6,352	6,180	12,532	3,958	58.40
1979	13,978	12,831	547	3,958	14,629	5	18,438	6,506	9,229	15,735	3,000	62.50
1980	14,543	13,215	404	3,000	11,122	27	14,149	5,891	5,926	11,817	2,668	74.70
1981	14,330	13,841	542	2,668	15,646	26	18,340	5,264	6,567	11,831	6,632	54.30
1982	11,345	9,734	590	6,632	11,963	20	18,615	5,512	5,207	10,719	7,937	59.40
1983	7,926	7,348	508	7,937	7,771	12	15,721	5,928	6,786	12,714	2,775	66.40
1984	11,145	10,379	600	2,775	12,982	24	15,781	5,540	6,215	11,755	4,102	57.80
1985	10,685	10,229	630	4,102	13,432	33	17,567	6,399	1,960	8,359	9,348	56.30
1986	10,045	8,468	552	9,348	9,731	3	19,082	7,452	6,684	14,136	5,026	52.40
1987	10,379	10,030	706	5,026	14,760	2	19,788	7,617	6,582	14,199	5,771	64.30
1988	12,515	11,948	619	5,771	15,411	5	21,187	7,782	6,148	13,930	7,092	56.60
1989	10,587	9,538	614	7,092	12,196	1	19,289	8,750	7,800	16,550	2,990	65.60

SOURCES: Various issues of agricultural statistics, Cotton and Wool Situation and Outlook, and Statistics on Cotton and Related Data, USDA.

Improvements in mill technology were being made in the United States. In 1828, John Thorp patented the basic elements of ring spinning (Lee, 1984). By 1840, there were approximately 850 mills in the United States that processed over 225,000 bales annually; in 1860, 1090 mills used some 840,000 bales of United States grown cotton (Brown, 1927). Cotton had become the primary cash crop of the South. Cotton textile manufacturing had become an important industry for the North and cotton lint a major agricultural export commodity for the United States.

Rapid expansion of cotton production in the southern states is attributable to four major factors: (a) environmental conditions suited for growth of the crop, (b) availability of a large, relatively unskilled labor force, (c) accessibility to large acreages of idle land suitable for cotton production, and (d) most importantly, strong markets for cotton. Extensive sections of Virginia, North Carolina, South Carolina, Georgia, Florida, Mississippi, Alabama, Louisiana, Texas, Arkansas, Tennessee and Missouri were suited for cotton production. In the pre-Civil War

Table 2. United States Cotton production by state during the 1791 to 1834 period (Brooks, 1911; Goulding and Dustan, 1919).

State	Year				
	1791	1801	1811	1821	1834
	lbs lint produced (x 10^6)				
South Carolina	1.5	20	40	50	65.5
Georgia	.5	10	20	45	75
Virginia		5	8	12	10
North Carolina		4	7	10	9.5
Tennessee		1	3	20	45
Louisiana			2	10	62
Mississippi				10	85
Alabama				20	85
TOTAL	2	40	80	177	437

period, cotton acreage expanded as far north as latitude 37° N and as far west as the 30- to 35-inch (80 to 90 cm) annual rainfall belt in Texas. Initially, cotton was grown mostly in the alluvial valleys and bottom lands adjacent to natural waterways; as the demand for land increased, production was expanded into the vast, unused, acreages of "hilly lands" and prairies.

Through the ages, cotton culture has been a labor intensive enterprise. The rapid advancement of cotton across the South was a prodigous, remarkable achievement because of the immense amount of hand labor that was required. Land had to be cleared with muscle, fire and axe. First, thousands and later millions of acres had to be hand-planted, hand-weeded, hand-thinned and hand-harvested. Much of this great expansion was accomplished with black slave labor.

Slaves were introduced into colonial America during the 1600s and used mainly in agricultural endeavors because of language barriers and a lack of technical skills needed in industrial work. In the late 1700s, slavery fell into disrepute, and all states agreed to legally abolish the practice by 1808. However, the tremendous increase in cotton acreage following the invention of the gin produced a simultaneous demand for a large number of unskilled laborers. To southern plantation owners, expansion of the slave population seemed to be the logical solution to the problem. In reality, less than 25 percent of the southern population that were engaged in agriculture owned slaves but the slave owners were also the large land holders and thus set the pattern for both cotton culture and the social structure in the South (Cohn, 1956).

The consequence was the development of a gigantic cotton monoculture which required much manual labor and employed few tools and machines. Since land was readily available, there was no immediate need for practices that would conserve soil resources and maintain their productivity. An extensive, rather than intensive, agricultural system developed. As production began to decline, old fields were abandoned and new ones were put to the plow. On the larger plantations, it was not uncommon for a portion of the labor force to be permanently assigned to clearing land for the establishment of new cotton fields (Cohn, 1956).

As cotton production expanded in response to increasing demand in the United States and abroad, a cotton marketing system was developed to serve the needs of the textile manufacturers and to bring together the broad sources of supply across the South. For the first time, efforts were made to standardize bale weights and the quality measurements of cotton lint. Where cotton had been handled by general traders and merchants, specialists in cotton buying and shipping appeared. These middlemen began to surface between the grower, the shipper, the importer, and the dealer selling to the spinners (Lee, 1928). Spinners began to employ the services of middlemen to keep them informed as to the qualities of cotton available, its location, its price, and, if possible, the mill requirements.

The unity among the states, that had been a strong factor in the formation and establishment of the new nation, encountered its first sectional rift over the slavery issue. By law, slavery was to have been abolished in 1808, but the South chose not to honor this legislation. After the War of 1812, the British exported huge quantities of low-cost textiles into the United States hoping to stifle its developing textile industry. The industrial North retaliated by successfully lobbying for tariffs on textile imports; the Europeans countered with stiff tariffs on imports of raw cotton from the United States. The tariffs effectively protected the industrial North, but the South suffered economically because of the poor trade relations with European buyers of raw cotton which resulted. Slavery, states rights and tariffs now became a sectional issue between the northern and southern states which divided the nation and, in 1861, plunged it into war.

THE 1862-1892 PERIOD

> "No, you dare not make war on cotton. No power on earth dare make war on cotton. Cotton is King!"
>
> Senator James A. Hammond
> Address to United States Senate
> March 4, 1859

During the Civil War, the South attempted to force the European powers to recognize the Confederacy by withholding cotton from domestic and export markets. In 1859, the South produced 3.8 million bales of cotton, exported 3.5 million bales and sold the remainder to domestic mills. By 1864, cotton production was less than 0.3 million bales and exports were only 18,000 bales (Brown, 1927; Lewis and Richmond, 1968). The cotton embargo severely affected the textile industries of England and France but failed to win their support for the Southern cause. The European countries, especially England, attempted to relieve the raw cotton shortages by developing and extending cotton production in their tropical possessions (Cohn, 1956; Bigwood, 1919). Although such efforts had little impact on cotton supplies, attempts by Great Britian to free itself of the strong dependence on American cotton continued into the 20th century (Bigwood, 1919).

The textile industry of the North was also affected by the War but not as severely as that of Europe. Like Europe, the North built large inventories of cotton prior to the hostilities, managed to maintain a clandestine cotton trade with the South during the war years and imported some of its cotton. Domestic consumption nevertheless fell from 0.84 million bales in 1859 to approximately 0.3 million bales annually during the War (Brown, 1927).

The South was economically and socially divided by the War and desperately in need of internal improvement following its aftermath. To attain self-sufficiency, the South again turned to cotton and within ten years, production and exports exceeded pre-war levels (Table 1). Great changes, however, had occurred. The plantation system was greatly weakened. Large land holdings were divided and the average farm size fell from 401 acres before the War to 229 acres in 1870 (Cohn, 1956). Small farmers, encouraged by relatively cheap land prices and readily availabile credit, began to buy up portions of the old plantations and to plant cotton.

The labor force also underwent a drastic change. Many former slaves and impoverished whites left the South after the War. Those that remained disliked working for wages but were willing to enter into share-cropping agreements (Brooks, 1911; Cohn, 1956). Prior to 1860, the ratio of whites to blacks engaged in cotton culture was 1 to 8, in 1875 it was 2 to 3.

For the first time, real interest developed in labor-saving machinery and better production practices that could be applied to cotton culture. With the break-up of the plantation system and the slave labor force, cotton culture began a gradual transition from extensive to intensive agriculture. Little fertilizer was used prior to 1860 (White, 1896), but, in the states east of the Mississippi usage increased dramatically after the War. Increased fertilizer use, mainly phosphorus and potash, contributed to the maintenance of cotton yields in the Old South, at least temporarily.

Variety development and selection also began to receive more attention as production expanded and growers noticed differences in the performance of varieties available to them (Brown and Ware, 1958; Lewis and Richmond, 1968; Niles and Feaster, 1984). As certain varieties became more popular, seed businesses developed. Although the developers of these varieties seldom had any technical training, most were inherently good observers and through mass selection were able to develop agronomically acceptable types that represented improvements over the parent stocks. In 1895, Tracy (1896) listed 118 varieties that had been used in commercial production since the late 1800s. The life of a cotton variety in those days tended to be brief. Tracy (1896) noted that of the 58 varieties named in census reports in 1880, only 6 were still in use by 1895.

Perhaps the greatest post-war change occurred on the economic fronts. The practice of extending credit to large cotton growers greatly influenced marketing arrangements. The big trading companies, organized in previous centuries, served as large supply stores for accumulating raw materials for export and storing finished goods for sale. These places were known as "factories" and the persons in charge as "factors." These companies supported the plantations by supplying raw materials. In return, the plantation planters were extended credit to produce cotton.

In time, the big factories broke up, and the persons operating as factors became independent and began operations of their own. The factors made connections with supply houses in England and furnished credit to planters (Bruchey, 1967). The factors followed seaport and river towns providing necessary supplies and a contact for selling cotton. In profitable years, planters expanded by using credit furnished by the factors. The factors accepted mortgages on the crop as security. As part of the contract, factors had the right to sell the planters' cotton and to charge a commission (Cox, 1953). When railroads were built, the factorage system spread to the smaller general stores. These stores furnished supplies on credit for mortgages on crops, tools and livestock. In turn, they generally sold the farmers' cotton at harvest for the existing market price. Thus, the cotton farmers were at the mercy of the creditors and stood all the risk of the market.

To expedite and efficiently market cotton in the United States and abroad, a recognized system for describing quality was essential. In the early 1800s, American cotton was known as New Orleans, Upland and Sea Island. Later terms such as Ordinary, Choice and Fair began to appear. In 1843, Middling Uplands or Middling Orleans was used and in 1853, in New York, brokers formed an association and adopted a set of standards. The recognized standard descriptions made possible the sale of cotton without buyers seeing the cotton.

The development of a cotton futures market was perhaps the greatest step in the evolution of the present system of cotton marketing. It revolutionized cotton marketing because cotton could be bought and sold in transit. Mills could make forward orders based on agreements with merchants for forward deliveries (Hoffman, 1932). Futures developed because of the extreme price fluctuations, industry growth, standardization of cotton classification and the development of the Atlantic Cable in 1866 which made immediate communication with Europe possible.

With the development and use of cotton futures markets, the market became distinctly worldwide. Hedging purchases for future delivery by merchants opened the cash market up to all the cotton produced during the harvest season. This made it possible to have large centralized markets that integrated the spinners, futures and local markets. The futures markets furnished a system of price insurance for all segments of the cotton industry.

With the post-war recovery in the textile industry and the improvements in marketing of cotton, the South was once again locked into a one-crop economy and to the factorage system of financing. To survive, the cotton producers had to expand acreage and production which led to lower prices. Cotton prices fell from 43.2 cents per pound in 1865 to 13.0 cents in 1875 and 9.4 cents in 1885; in 1865, the South produced 2.1 million bales, 4.3 million in 1875 and 6.3 million in 1885, (Table 1).

Despite these hurdles, the South, and cotton, was gradually gaining self-sufficiency. The development of the railroad system greatly facilitated the movement of goods and people and reduced the strong dependence on natural waterways as the principal means of transportation. By 1890, the railroad mileage in the South was more than twice what it had been in 1860 (Todd, 1950).

On May 15, 1862, Congress established the Department of Agriculture and in 1889 made it an executive agency. Although poorly funded and sparsely staffed, the Department was mandated to conduct agricultural and marketing research, some of which dealt with cotton production. The Morrill Act of 1862 provided for the establishment of agricultural colleges in the States and the Hatch Act of 1887 provided financial aid for the development of the state agricultural experiment stations. Serious scientific explorations of cotton production technology began to occur as the colleges and experiment stations were established in the South.

THE 1892-1935 PERIOD

> "The other difficulties of seasons, boll-worms and cotton caterpillars are natural, and not therefore entirely within the control of the planter; yet, we may reasonably hope that Providence will in the future dispose of them as in former years." (Cloud, 1866)

The somewhat nonchalant attitude of Dr. Cloud and other planters toward insects was partially justified in that up to 1892, cotton was produced in the United States without a major, annually recurring insect problem (Walker, 1984; Brown, 1927; Newsom and Brazzel, 1968). Prior to 1892, bollworms (*Heliothis* spp.) and cotton leafworms (*Alabama argillacea*) occasionally caused serious damage to cotton, usually late in the season (Comstock, 1879). Growers countered the problem mainly by timely planting and, to a lesser extent, selection of earlier maturing varieties and other cultural practices (Lyman, 1866; Brown, 1927). Some planters also experimented with biological and chemical (mainly arsenical) control agents (Comstock, 1879).

In 1892, however, the situation was drastically altered when the boll weevil (*Anthonomus grandis*, Boh.) crossed from Mexico into Texas and rapidly spread northward and eastward into the heart of the Cotton Belt. The boll weevil, apparently an ancient pest of cotton in its centers of origin in Central and South America, was, for many decades, ecologically isolated from the vast cotton production regions of the southern United States. Unlike other cotton insects which have one or more alternate hosts and may be held in check by predators or migrate into fields late in the season, the boll weevil is a one-host pest with few natural enemies that attacks the crop annually. It reproduces in geometrical proportions throughout the protracted fruiting cycle of cotton.

The boll weevil did considerable damage in Texas in 1894, entered Louisiana in 1903, Mississippi in 1907, Alabama in 1909 and completed its track to the Atlantic in the 1920s. Production losses associated with boll weevil infestations ranged from 25 to 50 percent (Parencia, 1978).

Newsome and Brazzel (1968) divided the time after boll weevil establishment into four periods, including: (a) before general use of insecticides, 1908-1923; and (b) widespread use of calcium arsenate, 1924-1945. During the first period, extensive efforts were made to develop cultural controls for the boll weevil. For the first time, modern plant breeding techniques were applied to cotton, mainly at recently established state and federal research facilities (Brown and Ware, 1958). The boll weevil forced producers and breeders to abandon the vigorous, late maturing upland cotton with relatively long fibers and to develop early maturing but shorter stapled cottons (Bennett, 1908; Niles and Feaster, 1984; Lewis and Richmond, 1968; Ware, 1951). Rapid adoption of the new varieties and cultural practices such as reduced row widths (Niles *et al.,* 1978) enabled producers to minimize boll weevil damage and maintain economically acceptable production levels.

The preference of the weevil for the high-rainfall regions of the Cotton Belt with long frost-free periods and abundant overwintering habitat was quickly recognized (Walker, 1984). As a result, cotton acreage began to decline in the 50+ inch (100+ cm) rainfall zones of the deep South and increase in the 20- to 30-inch (50 to 75 cm) zones, mainly in Texas and Oklahoma and in the northern reaches of the cotton producing states where cold winters and limited overwintering habitat restricted winter survival. With the development of irrigation, cotton production also gradually extended westward, away from the boll weevil, into New Mexico, Arizona and California (Todd, 1950).

The potential advantages of early crop termination and stalk destruction were recognized early on, but the practice was impractical because of the extended period required to harvest the crop by hand. An alternate solution was to control the weevil with insecticides. Numerous compounds were tested, and it was established that calcium arsenate would effectively control this pest. However, growers and entomologists soon learned that repeated applications of this insecticide often resulted in uncontrollable outbreaks of secondary pests such as the bollworm and aphids (Walker, 1984).

Consequently, cultural practices for control of the boll weevil remained in vogue and their application was introduced to growers through on-farm demonstrations such as those conducted by Seaman E. Knapp in Texas in 1903. Dr. Knapp's activities proved to be highly successful and contributed significantly to the introduction and passage of the Smith-Lever Act in 1914 which provided for the establishment of the state agricultural extension services.

The boll weevil did not cause the demise of the cotton industry as many predicted. Instead, acreage actually expanded from 20.2 million acres in 1892 to an all time high of 44.6 million acres in 1926 (Table 1, Figure 1). In the decade of 1910-19, the U.S. cotton crop accounted for nearly 60 percent of the total world production (Murray, 1950). Despite the presence of the weevil, yield levels increased from an average of 177 pounds per acre for the 1874-1894 period to 191 pounds for the 1895-1915 period (Brown, 1927). The improvement in yield may be construed as a tribute to the early plant breeders in that their "new" earlier maturing varieties were being grown not only in the traditional rainbelt regions but also in areas with drier climates and shorter growing seasons.

Insects were not the only pest problems attracting the attention of plant breeders. Diseases had been present in cotton growing areas of the U.S. since the very early periods of cotton culture but generally did not cause extensive damage until the change from an extensive to an intensive form of cotton culture (Presely and Bird, 1968). Serious attention began to be directed at plant pathogens in the late 1800s when Pammel (1888) reported that a fungus, *Phymatotrichum*, caused cotton root rot and Atkinson (1892) described bacterial blight (*Xanthomonas malvacearum*), fusarium wilt (*Fusarium oxysporium*), boll rots (several bacteria and fungi spp.), and root-knot nematode (*Meloidogyne incognita*) damage in Alabama. Fusarium wilt had become firmly entrenched in the areas of the Southeast where Sea Island cotton had been grown for many years. Mr. E. L. Rivers, a cotton producer, developed a variety resistant to the disease with the aid of USDA researchers (Presely and Bird, 1968). A few years later, one of these scientists, W. A. Orton, developed and released several upland varieties with resistance to this disease (Orton, 1908).

Prior to 1900, cotton breeding efforts were based on selection and the plant-to-row breeding method. After the rediscovery of Mendel's papers on genetics and the publication of Johannsen's pure line theory around 1900, hybridization began to be used as a technique to transfer desirable traits such as earliness, disease resistance and fiber quality (Lewis and Richmond, 1968; Niles and Feaster, 1984). Fiber improvement warranted immediate attention because the introduction of earliness resulted in shorter stapled cottons which were being penalized in the market place (Kerr, 1951).

As cotton production shifted westward into regions that were drier but with longer growing seasons, extra long staple (ELS) cottons, *Gossypium barbadense*, were introduced into Arizona and California. From introductions of cotton from Egypt, breeders made selections which resulted in the development of agronomically acceptable varieties for the West (Lewis and Richmond, 1968).

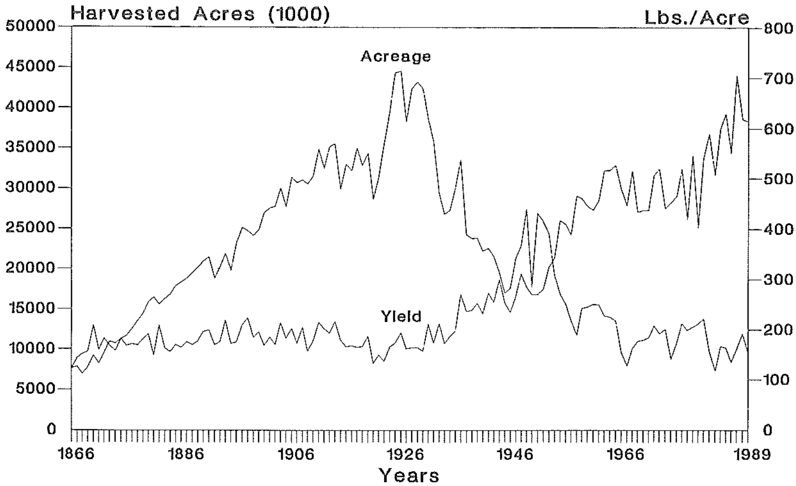

Figure 1. U.S. Cotton Acreage and Yield, 1866-1989.

The United States acreage of ELS cotton reached 240,000 acres in 1920 but declined to less than 40,000 in the 1930s (Starbird *et al.,* 1987).

During the 19th and early 20th centuries, numerous studies were conducted to ascertain the importance of various fertilizer elements in cotton production (Brown, 1927; Tucker and Tucker, 1967; Jones and Bardsley, 1968; Kamprath and Welch, 1968; Hinkle and Brown, 1968). Whereas little fertilizer was used on cotton prior to the Civil War, over 14 million of the 38.3 million acres planted in 1923 were treated with manure or some form of commercial fertilizer (Brown, 1927). Most of the fertilizer used during this period was confined to the traditional cotton production areas of the deep South where annual rainfall was typically in excess of 50 inches (125 cm) annually.

Production techniques remained relatively static until about 1930. Planting and cultivation continued to be done with animal drawn equipment, and weed control and thinning were accomplished manually with the hoe. As labor became scarcer and more expensive, greater emphasis was placed on mechanization and the use of equipment in stand establishment and crop maintenance.

The structure of the cotton marketing system continually changed to meet supply and demand conditions. This system is made up of farmers, warehousemen, merchants, manufacturers, converters, wholesalers, and retailers that perform the necessary functions to make cotton goods available to consumers. Hedging price risk on futures contracts made it possible for the development of large cotton merchandising firms. These firms accumulated cotton from growers through local cotton buyers and classed it into even-running lots for sale to mills.

The system of local buyers scattered over the cotton production areas was effective but resulted in fairly restricted, and widely fluctuating, markets for growers.

Because of the worldwide market and wide range in quality, a standardization of price determining factors was needed. Early cotton grading began in Liverpool in 1800. After World War I, the United States began to set up cotton standards that were to be recognized around the world. The methods of selling cotton used to reflect quality were as follows: (a) by actual sample of cotton lint from the bale; (b) on type by a group of samples representing grade, staple, and character without reference to individual bales; and (c) on description that was equal to a certain grade and staple.

The instability of cotton prices and markets in the United States was due to the long standing difficulties in matching supply and demand. Cotton production had increased from about 2 million bales in 1866 (McArthur, 1980) to nearly 18 million bales in 1926. During the same period, harvested acres increased from 7.7 million in 1866 to an all-time high of 44.6 million in 1926 (Table 1.) Throughout the period, however, cotton yields averaged about 190 pounds per harvested acre and rarely exceeded 200 pounds per acre (Miller, 1977). For cotton production to remain profitable, improvements in production technology were needed.

THE 1936-1965 PERIOD

> "Cotton is a very jealous plant and will not struggle with weeds or grass for a division of the fertilizing properties of the soil. It will not grow unless kept very clean and the full energy of the soil is kept concentrated on it alone." (Lyman, 1866)

Beginning in the mid-1930s, yields began to increase and acreages to decline (Figure 1 and Table 1). There were a number of economic and agronomic reasons for these changes. Government farm programs that spanned the 1933-65 period usually included acreage allotments, marketing quotas and parity price supports (Starbird *et al.*, 1987). The troubled economic times associated with the Great Depression set the cotton industry back substantially. The economic crisis was very severe across the farm sector, especially after World War I. The Agricultural Marketing Act of 1929 was enacted to make loans to marketing cooperatives for the purchase and storage of surplus commodities including cotton (Starbird *et al.*, 1984). Because of declining demand and lack of production controls, the Federal Farm Board, created by the 1929 Act, failed to stabilize prices or increase farm income.

The Agricultural Adjustment Act of 1933 followed and was aimed at controlling production and increasing prices (Bowers, 1984). This was the first federal farm program to affect cotton. Since then, cotton programs have contained many of the features of this first program. These included payments for voluntary acreage reduction, payments to increase farm income, price support loans and allotments to use in determining farm payments. Providing payments, even though no cotton was planted, was a form of disaster protection. There also were rules as to what crops could be planted on acreage taken out of cotton.

Through such programs, marginal acreages were diverted to alternate crops or to soil-conserving crops such as grasses and legumes. By the 1960s, cotton had largely moved out of the hilly areas of the Cotton Belt states to the deeper, more fertile, relatively level soil resource areas that are not only more productive but better suited for farming with large equipment (McArthur *et al.*, 1980). Fertilizer use increased dramatically, especially after World War II, when a scientific basis for determining fertilizer use in specific areas or on given soils began to be established and appropriate commercial fertilizers were formulated to accommodate such recommendations.

As agriculture became more mechanized, tremendous strides were made in the development of equipment for production of cotton. Planters, cultivators, fertilizer and chemical applicators, mechanical cotton choppers, flame cultivators, stalk cutters, shredders, disks, listers, moldboard plows and chisels were just some of the tools developed or improved and enlarged as cotton producers changed from animal power to row-crop tractors (Smith, 1950). Improved equipment and tractor power provided the means for performing cultural operations in a timely manner, for correcting soil physical problems such as hardpans with deeper tillage than heretofore possible and for utilizing newly developed chemical pest control agents.

Cotton mechanization during this period had major impacts on two production components—weed control and harvesting, both of which required extensive hand labor. Progress in mechanization needed to be parallel in these two production sectors, as seasonal labor to perform only one of these labor intensive operations simply could not be kept available. The dual switch from hand-labor to chemical weed control and from hand to mechanical harvesting freed a significant percentage of the population in cotton producing areas from a life of very hard labor but it also created new sociological and economic problems for farm workers.

The general design of the mechanical cotton picker, which became the industry standard, was developed prior to World War II and production models started penetrating the industry in the late 1940s. Stripper harvesters were developed almost concurrently. Strippers are much simpler and cheaper to operate, but gather more foreign material along with the cotton. As a result, stripped cotton requires more cleaning machinery at the gin. Strippers were developed in Texas and are used predominantly in the Texas-Oklahoma production region.

In 1947, 98 percent of the United States cotton crop was hand-picked or hand-snapped (Fortenberry, 1956), whereas in 1957 only 68 percent of the crop was hand-harvested. Thus, machine-harvesting had increased from 2 to 32 percent in 10 years—an average of 3 percent per year (Table 3). The change to mechanical harvesting accelerated rapidly beyond this point and by 1962, 70 percent of the United States cotton crop was machine-harvested—an average increase of 7.5

Table 3. The percentages of United States cotton harvested by hand and by machine from 1947 to 1970.

	Harvest method						
	Hand			Machine			
Crop	Picked	Snapped	Total	Picked	Stripped	Scrapped	Total
	(Percent)						
1947	77	21	98	—	—	—	2
1948	—	—	—	—	—	—	—
1949	68	26	94	—	—	—	6
1950	71	21	92	—	—	—	8
1951	61	24	85	—	—	—	15
1952	63	19	82	—	—	—	18
1953	—	—	—	—	—	—	—
1954	54	24	78	—	—	—	22
1955	54	23	77	17	6	0	23
1956	53	20	73	20	7	0	27
1957	44	24	68	19	13	0	32
1958	44	22	66	21	13	0	34
1959	39	18	57	31	12	0	43
1960	33	16	49	36	15	0	51
1961	27	14	41	39	19	1	59
1962	20	10	30	48	20	2	70
1963	21	7	28	51	20	1	72
1964	16	6	22	58	19	1	78
1965	11	4	15	60	24	1	85
1966	8	3	11	61	27	1	89
1967	5	1	6	67	26	1	94
1968	3	1	4	68	27	1	96
1969	3	1	4	71	24	1	96
1970	2	0	2	71	26	1	98

Source: Ghetti and Looney, 1982.

percent per year. This trend continued until 1970 when 98 percent of the crop was machine harvested (Ghetti and Looney, 1982). Currently, a hand-harvested bale of cotton is very rare in the United States.

Mechanically harvested seedcotton which contained more foreign material, created a need for more cleaning at the gin in order to deliver satisfactory fiber to textile mills. To remove as much of this foreign material as practical, seedcotton cleaners (including incline cleaners, impact cleaners, stick machines and bur machines) and lint cleaners were developed. Because cotton (either seedcotton or lint) cleans much easier when it is dry, more seedcotton drying equipment was also needed in gins. In response to mechanical harvesting, gins quickly installed additional drying and cleaning equipment in the late 1950s. By 1960, 93 percent of the gins operating in the United States had some seedcotton drying equipment; of this total, 40 percent had two stages, and 6 percent had three stages. At that time, 85 percent of the gins had some type of lint cleaning; of these, 38 percent had two stages, and 4 percent had three stages.

A strong factor contributing to the yield improvements of this period was the development of chemicals that effectively controlled many weed, insect and disease pests and which conditioned the crop for timely harvest with mechanical harvesters. Mechanical devices such as cultivators, rotary weeders, flame cultivators and even mechanical choppers were helpful in eliminating many weeds but did not provide adequate control of weeds within the cotton drill (Brown and Ware, 1958; Christidi and Harrison, 1951). Selective herbicides began to appear in the late 1940s and early 1950s (Ridgeway *et al.*, 1984; Ennis, 1962, McWhorter and Holstun, 1966; Holstun and Wooten, 1968). Herbicide usage in cotton began to gain some farm acceptance in the 1950s and by the 1960s constituted the primary means of weed control.

Prior to World War II, the boll weevil remained a nemesis to cotton. Calcium arsenate effectively controlled the boll weevil but triggered secondary outbreaks of *Heliothis* spp. and cotton aphids (*Aphis gossypii*). After World War II, the chlorinated hydrocarbon insecticides provided cost-effective control of not only the boll weevil but the secondary pests as well (Walker, 1984; Newsom and Brazzel, 1964; Ridgeway *et al.*, 1984). By the mid-1960s, the organophosphate and carbamate classes of insecticides were also available and widely used. For a time, the cultural management techniques for suppression of the boll weevil and other insect pests were totally or partially ignored because the new insecticides seemed to provide a total solution to cotton insect problems.

By the mid- to late-1950s, however, failures of the synthetic organic insecticides to control all insects were noted and environmental concerns began to develop about the increasing use of pesticides. The development of resistance, elevation of secondary insects to major pest status and rising costs of chemical control measures called for a re-examination of insect control strategies. For the time being, however, growers were strongly dependent on available insecticides to deal with their ever increasing cotton insect problems.

The need to obtain timely uniform stands of cotton and protect seedlings from various pathogens prompted the development and widespread use of fungicides (Presley and Bird, 1968). Organic and inorganic fungicides were used as seed, hopperbox and/or in-furrow treatments to provide control of seedling diseases. Fumigants were used to control nematodes. To a large extent, however, growers were relying on plant breeders to develop cultivars with genetic resistance to the major disease pests (Bird, 1980).

The advent of mechanical harvesters developed a need for preparation of the cotton plant for harvest. The efficiency of the picker is dependent on removing much of the foliage and reducing the moisture of the remaining leaves prior to harvest. For stripper harvesting, the principle requirement is complete desiccation of foliage and stems before harvest.

Chemical defoliation of cotton was discovered in South Carolina in 1938 and gained rapid acceptance as machine pickers became available (Smith, 1950b; Cathey, 1986; Walhood and Addicott, 1968). Likewise, the desiccants, primarily arsenic acid, gained rapid acceptance as stripper harvesters were introduced into the Southwest.

Plant breeders made significant improvements in: (a) plant conformation to accommodate machine harvesting, (b) enhanced earliness in both the upland and ELS cottons, (c) improved fiber properties (mainly length), (d) pest resistance and (e) environmental stress tolerance (Niles and Feaster, 1984; Lewis and Richmond, 1968). During this period, a strong cotton planting seed industry developed to complement public and private breeding efforts. Private companies produced, harvested and processed proprietary, and in some instances, state released varieties for sale to producers. By the mid 1960s, most of the commercially processed planting seed were flame or acid delinted and treated with fungicides.

Most states instituted seed certification programs to ensure genetic purity and, in some cases, quality standards of the planting seed sold to producers. Laboratory tests were developed to ascertain the viability and vigor of cottonseed (Baskin *et al.*, 1986; Delouche, 1986; Cherry and Leffler, 1984), and public and private laboratories provided seed testing services to seedsmen and producers. The Association of Official Seed Analysts was formed to standardize seed testing procedures for several crops, including cotton.

THE 1966-1986 PERIOD

From 1966 through 1980, the acreage of cotton harvested in the United States fluctuated greatly but showed no clear trends (Figure 1, Table 1). Lint yields during this period, however, actually declined by about 0.8 pounds per acre per year (Meredith, 1982). In some production regions such as the Texas High Plains, even sharper declines were noted (Neal and Ethridge, 1984). From studies conducted to assess the reasons for the yield decline, it was generally concluded that the factors responsible varied from region to region (Brown, 1977; Neal and Ethridge, 1984; Meredith, 1982; Meredith, 1987; Neal *et al.*, 1984) and were closely linked to economic considerations. For example, in the Delta states, the decline appeared to be associated with insect control, especially of early-season pests (Meredith, 1987); whereas, on the Texas High Plains, declining yields appear to be more a function of reduced irrigation and fertilizer usage (Neal and

Ethridge, 1986; Wanjura and Barker, 1986). The cost-price squeeze that began in the 1970s forced many producers to reduce input costs which in turn had a negative impact on yields (Starbird *et al.*, 1987). Some improvements in yields were noted during the 1981-85 period and are attributed to more widespread usage of new technology, better management and the shift to more irrigated production.

Rather impressive improvements have been made in the culture, mechanization and marketing of cotton during the last two decades. Starbird *et al.* (1987) recently reviewed the production practices currently in use in the various sections of the Cotton Belt. Widespread mechanization has reduced dependence on hand labor, improved timeliness of all operations from land preparation through harvest and contributed to the increasing size of modern-day farms. Currently used herbicides are highly selective for cotton and control a broad spectrum of grassy and broadleaf weeds. These have largely replaced hand hoeing as the primary method of weed control. In 1976, approximately 18.3 million pounds of herbicides were used on cotton. The average cost of these chemicals was $10.33 per acre. Achieving equivalent levels of weed control by hand hoeing and additional tillage would have cost $29.39 per acre (Abernathy, 1981).

Integrated pest management (IPM) was introduced in the early-1970s as a means of dealing with insect resistance to certain insecticides and the steadily increasing costs of chemical control measures. The IPM approach utilizes both old and newly developed classes of insecticides in combination with cultural practices to provide cost effective control measures for insect pests.

Fertilizers have become primary production inputs in most production regions and soil testing is widely used to establish fertilizer requirements on a field-by-field basis. In the 1970s, plant growth regulators were introduced for controlling plant size, enhancing earliness and hastening boll-opening (Walter *et al.*, 1980; Cathy *et al.*, 1982; Cathey and Thomas, 1986). Parvin *et al.* (1987), Ray and Minton (1973) and others have shown that the yield and value of cotton deteriorates rapidly if harvest is not initiated when the crop is ready. A strategy has evolved in recent years to control plant size, advance maturity, terminate fruiting, induce senescence and/or open bolls with plant growth regulators and to defoliate or desiccate the crop with harvest-aid chemicals to prepare it for timely harvest (Cathey, 1986; Colwick *et al.*, 1984). Such practices are also important in the management of the boll weevil, pink bollworms and other cotton pests.

Improvements in varieties are continually being made by public and private breeders in response to changing cultural practices, pest pressures and mill needs (Niles and Feaster, 1984; Bridge and McDonald, 1987; Gannaway and Dever, 1986). The yielding ability of cotton has been steadily enhanced through genetic improvement. Miller (1977) estimated that the varieties grown in the mid-1970s had the genetic potential to yield 2 to 17 percent more than varieties grown in 1965. Bridge and Meredith (1983) compared the performance of obsolete and current varieties in Mississippi and found that for the 1910 to 1979 period, yields increased at the rate of 7.7 pounds per acre (8.6 kg/ha) per year as a result of genetic improvement.

Much of the genetic improvement in yield is attributed to the ability of modern cultivars to partition more dry matter into reproductive structures (Wells and Meredith, 1984). As a result, the newer varieties tend to be shorter, more compact and earlier maturing as well as more productive. The widespread acceptance of these varieties, especially in the Mid-South and Southwest, and the adoption of better management practices has tended to decrease the number of days required to produce the crop. Within the last 20 years or so, the length of the planting to harvest period has decreased by 1.18 days per year in Stoneville, Mississippi; 1.33 days in College Station, Texas; and 2.43 days in Florence, South Carolina (Bridge and McDonald, 1987). The increasing acceptance of narrow-row culture is expected to create a need for additional cultivars which are early maturing, develop compact plants with short fruiting limbs and produce fiber that more precisely meets the needs of yarn and fabric manufacturers.

With an increase in the size of individual farming operations, higher costs of inputs and narrower profit margins, management becomes critical. Modern digital computers have made it possible to develop crop simulation models with application in research management, plant breeding, yield forecasting, and pest control as well as in crop management (Baker, 1980). GOSSYM-COMAX, a crop simulation model and expert system, was made available for on-farm use in the 1980s (Creech, 1986; Mullendore, 1986) and is designed to aid in cotton management by predicting growth events and by assessing the need for nitrogen and water inputs to achieve desired yield levels. Currently, several other cotton simulation models are also under development (Wade, 1987).

The development of the modular system for handling seedcotton from the field to the gin was one of the most significant engineering accomplishments in the history of the cotton industry, rivaled only by the invention of the gin and the mechanical harvesters. Modular systems were first used commercially in 1974 when two percent of the crop was moduled. Since 1980, 32 to 42 percent of the crops have been moduled. The modular system is a transportation and storage system, but its economic advantages come primarily from storage components (Willcutt and Mayfield, 1985). The system includes a builder which receives seedcotton from the harvester and compacts it into a free standing module in the field. A transporter picks modules off the ground and moves them from the field to the gin. The modules are then fed into the gin with either an automatic module feeder or with a conventional suction system. With the modular system, ginning capacity no longer has to equal harvesting capacity. The net effect is that gins can be operated more hours per year, improving their utilization efficiency and reducing ginning costs.

The universal density (UD) gin press was also a significant development during this period. The cotton industry began an organized program to adopt the universal density bale as an industry standard in 1970. Prior to the UD gin press, most bales were compressed at the gin to a low density, then recompressed at a central facility to either standard density or high density. This non-uniformity created handling and transportation problems and added unnecessary recompression and handling costs. By 1985, approximately 65 percent of the crop was packaged to its final density by UD gin presses.

The high volume instrument (HVI) system of classing cotton was introduced to the industry in the early-1980s. This system generally evolved from laboratory equipment and methodology that had been used for several years. The current cotton classification system typically uses a combination of manual and machine quality evaluations. The grade is determined by a classer, and the micronaire, length, and strength by machine. Over the last few years, 30 to 40 percent of the crop has been classed on HVI.

Other significant developments during this period focused on increased size and capacity of farm machinery. One and two-row cotton pickers were replaced with two- and four-row models. Improvements were also made in harvester operation, efficiency and maintenance. Gins have increased in size and complexity. The average annual volume per gin increased from approximately 3,000 bales in 1965 to approximately 7,300 bales in 1985, while the number of active gins decreased from 4,870 to 1,772. Individual gin machinery became larger with more capacity, safer, more reliable and more automated.

Government programs continued to play a major role in attempts to adjust supply to demand and prop farm income up during periods of very low prices. The Food and Agriculture Act of 1965 attempted to do just that. This Act was somewhat market-oriented in that it supported cotton at 90 percent of estimated world price levels. The Agricultural Act of 1970 set up a voluntary program for cotton as marketing quotas were suspended for three years. It also put a $50,000 annual limit on direct government payments to producers of upland cotton, wheat and feed grains.

By 1973, the worldwide demand for American farm products surged due to world crop shortages, devaluation of the dollar and economic growth worldwide. The agricultural environment progressed from chronic surpluses and low producer income problems to a situation where the government could reduce its regulatory role as well as the cost of farm programs. A new target price concept was introduced in the 1973 Act. If market prices received were under target price levels, then a payment for the difference was made to the producer to support farm incomes. The 1973 Act also introduced disaster payments. Cotton producers, who were prevented from planting or who suffered low yields due to a natural disaster, received a payment based on a percentage of the target price level. Disaster payments were made for each of the 1974 to 1982 crop years. A price and income safety net for growers that would not disrupt market prices was the major objective of the 1973 and 1977 Acts.

The Agriculture and Food Act of 1981 extended cotton provisions of the 1977 Act. Disaster payments were to be phased out and replaced with all-risk Federal

Crop Insurance Corporation (FCIC) insurance. The Food Security Act of 1985 was designed to make agricultural commodities more competitive in the world market. The cotton program's objectives were to protect farm income and to lower carryover stocks to workable levels through the use of a marketing loan and a competitive price. In effect, the marketing loan assured that United States cotton would be competitively priced with foreign growths.

The productivity of American cotton growers has generally outstripped growth in demand for cotton. Farmers have worked to increase their efficiency to escape the squeeze between rising production costs and the slow advance in prices paid for their commodities (Anderson, 1972). The result has been basic changes in the structure of the cotton industry—a decline in number of cotton farmers and a continuation of improvements in production techniques. These changes have cut not only the number of acres required for production of cotton but also the labor required.

As the productivity of growers increased, development of new synthetic fibers and changes in consumer preferences reduced the demand for cotton. Particularly significant was the growth in domestic use of synthetic fibers, which invaded many traditional cotton markets (National Advisory Commission on Food and Fiber, 1967). Total United States fiber consumption, including the raw fiber equivalent of textile imports, rose from about 4.7 billion pounds during 1940 to about 12.5 billion pounds in 1978 (Starbird *et al.*, 1987). Population growth, rapidly rising real incomes, changing lifestyles, the invention of new textile products and decreases in real fiber prices contributed to the increase in fiber consumption. Per capita fiber use rose from about 34 pounds in 1949 to about 56 pounds in 1978. But, total and per capita fiber consumption fell during 1979-82 to 10.5 billion pounds and 45 pounds, but then increased to about 13.5 billion pounds and 57 pounds in 1985.

However, despite the increased fiber consumption, domestic use of cotton declined from a post-war peak of 10.5 million bales in 1950 to 5.3 million bales in 1981, before rebounding to 8.8 million bales in 1989, Table 1. Cotton use per capita was 21.6 pounds in 1988, compared with 25.2 pounds in 1966. Loss of cotton's market share was due mainly to polyester and nylon. Cotton accounted for 81 percent of total United States fiber consumption in 1940, 53 percent in 1966, and about 32 percent in 1988 (Sandford, 1990).

Cotton consumption has been reduced by both competition with man-made fibers and by growth in the cotton textile trade deficit. Following the 1950s, cotton lost market share to polyester and nylon because of their easier care, durability, and the desirable spinning characteristics of synthetic fiber. Also, man-made fiber prices are more stable than cotton prices. Because of the adversities of weather and response to big changes in price levels, cotton production is erratic from year-to-year. The uncertainty of cotton prices, combined with polyester's stable price advantage, contributed to loss of market share of cotton. Unlike the cotton industry with its many producers selling through a series of market channels, the synthetic fiber industry was made up of a small number of large manufacturers, and was able to gear its production to its market thereby becoming a highly efficient competitor. Cotton's major advantages over man-made fibers are its absorbency, softness and breathability. Although foreign use of cotton has tripled since World War II, domestic use has shown little change.

To support farm income in a rapidly changing market situation, the government has tried through various farm programs for more than half a century to cope with the problem of overcapacity. Only since the mid-sixties has the cotton industry given more attention to expanding consumer demand for cotton. Programs began reflecting a newfound emphasis on efforts to counter the steady decline in demand for cotton by improving its competitive position. The most direct government effort to influence demand came with the Cotton Research and Promotion Act of 1966. This legislation established a program of self-help in the expansion of cotton markets. New programs were designed to allow the price of cotton to seek competitive levels at home and abroad.

THE FUTURE FOR COTTON

The immediate future for the United States cotton industry appears bright. On the demand side, consumers around the world are favoring cotton goods. World cotton consumption has increased in excess of 20 million bales during the last decade. The United States textile industry is making strides in upgrading the quality of cotton garments and in the production efficiency of manufacturing cotton textiles. This makes for a more competitive industry in the international market as well as in the United States with textile imports. Growers are also producing a higher quality fiber in response to the needs of their textile mill customers and the development of a HVI cotton testing system which provide a means for rapidly measuring fiber parameters such as length, strength, color and elongation. As a result, cotton is now more competitive with synthetic fibers.

On the supply side, based on the productivity of American cotton growers, United States cotton can compete at international market price levels. However, given this country's tremendous production potential, acreage reduction programs will continue to be needed to help balance supply with demand, and maintain stocks at desired levels.

Biotechnology is likely to have a major impact on cotton culture in the coming decades. Recombinant DNA technology and tissue and cell culture coupled with traditional breeding programs may markedly reduce the time required to generate new varieties. Genetic resistance to insects and diseases, earliness, enhanced tolerance to specific herbicides and environmental stresses, improvements in fiber properties and in seed quality are among the traits that will continue to be stressed in variety development programs. The use of crop simulation models and expert systems as crop management aids is expected to increase as these models are refined and producers become more acquainted with their capabilities. Growers are also likely to make greater use of telecommunication networks which continuously update marketing and production information.

The advantages of narrow-row culture in which plant populations are optimized to make the best use of light, water and nutrients are already apparent to growers and widespread adoption of this practice is likely within the next decade. Conservation tillage systems offer a means for reducing production costs, affording crop protection from environmental hazards and meeting governmental erosion control guidelines. The use of supplemental irrigation in the rainbelt states is likely to increase as growers strive to minimize stress conditions that negatively impact yields. Synthetic plant growth regulators have great potential for modifying plant growth, water use characteristics and susceptibility to pests. The protection against pests that is now offered by chemicals will need to be complemented with new chemistry, as well as with genetic, biological and management approaches.

Industry trends in developing machinery to meet the ever-changing needs of cotton producers will continue at an accelerated pace. Equipment developed for conventional and conservation tillage systems will tend to combine tillage operations to reduce the number of trips through the field. In irrigated areas, greater use will be made of the drip systems and multifunction sprinkler systems which not only deliver water with minimal evaporation and runoff losses but will also precisely place fertilizers and pesticides. In time, the multi-function sprinkler systems may even replace some traditional tractor operations.

A complete instrument system of evaluating the quality of cotton must be developed and adopted by all segments of the industry from the producer to the textile manufacturer. This change will force the marketing system to put fair premiums on the fiber quality factors that are required by textile manufacturers. The premiums should make it profitable for producers to deliver the fiber quality which the textile manufacturer needs.

SUMMARY

From a humble beginning as a garden crop used to provide for domestic textile needs, cotton developed into a major agricultural commodity in the United States. The industrial revolution in England resulted in the mechanization of textile processing and generated a tremendous demand for cotton. Vast areas of the southern United States were suited for cotton production, but the crop did not attain economic significance until the invention of the cotton saw gin. Until well after the Civil War, a gigantic cotton monoculture existed in the South which was largely dependent on manual labor and an extensive, rather than intensive form of agriculture.

For nearly 100 years, cotton was grown without interference from a major, annually recurring insect pest. In 1892, the invasion of the boll weevil forced major changes in cotton culture and greatly contributed to the westward movement of the crop. Technological breakthroughs in the development of mechanical cotton harvestors and selective cotton herbicides allowed near complete mechanization of cotton culture.

As the productivity of cotton producers increased, development of synthetic fibers and changes in consumer preferences reduced the demand for cotton both domestically and abroad. Since the mid 1960s, the cotton industry has provided attention to both increasing production efficiency and improving its competitive position relative to manmade fibers. Despite continued challenges, the immediate outlook for the United States cotton industry appears bright. The challenge of the future will be to combine technology, management and natural resources into a system that produces high quality cotton textiles at a cost competitive with synthetics and foreign cotton products.

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