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Signed:  ____Jill Holbrook____

Date:  ____July 15, 2019____
HOW FIBER CHARACTERISTICS AND PREPARATION OF COTTON AFFECT THE EASE AND CONSISTENCY OF HAND SPINNING COTTON

By

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ABSTRACT

Cotton is considered difficult to spin by some modern spinners. Examining multiple aspects of cotton from its origins, through history, to the science and types of cotton has shown the many aspects and value of this fiber. Various preparations for spinning cotton were explored using ancient and current techniques as well as commercial preparations such as sliver and combed cotton from mills. These preparations and techniques demonstrate the ease of spinning cotton. Samples of raw cotton and handspun yarns using the different preparations for spinning are included in this study.
ACKNOWLEDGEMENTS

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Mary Snyder, a friend and talented designer, re-created a spindle similar to those used in the prehistoric Southwest. One of these spindles was used to spin some of the handspun yarns in this study.

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How Fiber Characteristics and Preparation of Cotton Affect the Ease and Consistency of Hand Spinning Cotton

In general, the hand spinning community perceives cotton as difficult to spin. History shows that cotton was the primary fiber in many temperate climates and was spun with skill on spindles and wheels for millennia. This study examines the characteristics and various preparations of cotton to evaluate the best methods for spinning cotton into yarn with ease and consistency.

The Origins of Cotton

Around 150 million years ago, the supercontinent called Pangaea (Figure 1) was breaking up. As the continents began to drift, the change in the ocean currents significantly affected climates causing plants that required spore reproduction (i.e., ferns, mushrooms) to fail, while flowering plants that produced seeds were thriving (Wikipedia, Pangaea, 2016). In the area of Africa/South America, the earliest flowering plants began that would eventually spawn cotton plants.

The New World continents (the Americas) and the Old World continents (Europe, Asia and Africa) were separated within 65 to 50 million years. Finally, 10 to 15 million years ago, some of the flowering plants became the first cottons. The cotton plants were
separated from their relatives and the genus *Gossypium* was named for all cotton species (Wendel & Grover, 2015, p. 27).

Now, there are more than 50 species in the *Gossypium* genus. Many of these species are wild and some are newly discovered. One of the fascinating things about cotton is its global presence due to its diversity and “transoceanic, long distance dispersals and wide hybridization among lineages that presently are widely separated geographically” (Wendel & Grover, 2015, p. 25).

Cottons with sufficient fibers for spinning have been used by ancient and modern people for thousands of years. Four cottons became the most cultivated and utilized for textiles and food. There are two in the Old World, one in the area of India and Pakistan, *Gossypium arboreum*, and one in Sub-Saharan Africa and Arabia, *Gossypium herbaceum*. *Gossypium arboreum* has been, and continues to be, an important crop in India. *Gossypium herbaceum* was an important cotton crop in earlier times but today it is grown for local use in the drier areas of Africa and Asia (Lee and Fang, 2015, p. 1).

The two cottons in the New World are *Gossypium hirsutum* and *Gossypium barbadense* (Wendel and Grover, 2015, p. 39). *Gossypium hirsutum* began in Mesoamerica, northern South America, the West Indies, and the southern tip of Florida. *Gossypium barbadense* thrived along the coasts of Peru and Ecuador, the West Indies, parts of Mesoamerica and the upper portion of South America. (Lee and Fang, 2015, p. 9)

**THE HISTORY OF PEOPLE WITH COTTON**

Cotton fiber and cotton textiles disintegrate with exposure to sun and water. Intact bits of cotton and fragments of textiles from the ancient peoples were preserved in dry caves. Archaeologists and archaeobotanists are masters at finding, identifying and
interpreting these artifacts providing a glimpse into the prehistoric world of cotton, yarn and textiles.

The earliest date for prehistoric domesticated cotton varies from 7,000 to 5,500 years ago (Hochberg, 1979, p. 19; Lee & Fang, 2015, p. 9). Evidence of cultivation of *Gossypium hirsutum*, was noted in the Tehuacán Valley in Mexico in this time period. At the same time, Peru and Ecuador were the areas considered to be the beginning of *Gossypium barbadense* (Porcher & Fick, 2005, p. 74). On the central coast of Peru in the Ancon-Chillon Valley, 4,500 years ago, people were cultivating and just beginning to domesticate cotton (Lee & Fang, 2015, p. 8).

The oldest prehistoric civilization in the Americas began along the Pacific coast of Peru, called Norte Chico, around 5,000 years ago. There were many cities, thirty or more. Three rivers merged together and ran into the Pacific Ocean providing rich soil and easy irrigation for agriculture including cotton (Wikipedia, *Norte Chico Civilization*, 2016). Mann (2011, p. 211) called Norte Chico “the realm of King Cotton”. The people who lived in the valleys irrigated crops of cotton, squash, beans, guava, avocado and more. In the coastal cities, the people fished for clams, mussels, anchovies and sardines. They traded with each other for their mutual benefit, exchanging cotton and food crops for fish. This civilization lasted over 1,200 years (New World Encyclopedia, 2015).

Slowly, through trade, travel and migration, cotton spread to the North American Southwest. At least 2,300 years ago, the Hohokam were cultivating and weaving with cotton in Arizona (Menke, Yoklic, & Jensen, 2002, p. 2). In 500 CE, the Hohokam made dams and canals to irrigate their food and cotton crops (Menke, Yoklic, & Jensen, 2002, p. 2). By 700 CE, cotton textiles were common in Arizona (Teague, 1998, p. 21). The
Hohokam, Ancestral Puebloans, and Mogollon used cotton in ceremonies and rituals (Schoeser, 2003, p. 86). Cotton was revered and believed to be part of life with “associations between the breath, water, clouds, and rain”. (G. Dean, personal communication, August 15, 2016).

From 1250 CE to 1600 CE, the Ancestral Puebloans were growing cotton in the highlands of New Mexico, an area where cotton does not usually grow. The people managed the fields by mulching them with pebbles. The pebbles kept the soil warm and retained moisture, including snow melt. Corn, squash and cotton were grown together in altitudes above 6000 feet (Dean, 1996, p. 353).

The Hohokam and Ancestral Puebloans left their dwellings and towns in the 1400’s. They may have left the desert areas due to drought. The Pima and Tohono O’odham in Arizona and the Pueblos in Arizona and New Mexico are the descendants of these people (Menke, Yoklic & Jensen, 2002, p. 3). These descendants were growing cotton when the Spanish came.

The Spanish arrived in the 1500s, starting in Mexico and exploring their way into the American Southwest. Some of the Spanish conquistadors exchanged their scratchy wool clothing for the cotton clothing the native peoples were growing and weaving (Mann, 2011, p. 211), but they also brought sheep to the New World. Wool was faster and easier to process than cotton. Wool became the dominant fiber especially in northern Arizona and New Mexico. Cotton cultivation diminished.

In the 1600s the English came to the Atlantic coast. They brought cotton with them and planted it in Virginia in 1607 (National Cotton Council, 2016). The first crop failed but later crops were successful.
President Thomas Jefferson wrote about home grown cotton in 1796:

The four southernmost States make a great deal of cotton. Their poor are almost entirely clothed with it in winter and summer. In winter they wear shirts of it and outer clothing of cotton and wool mixed. The dress of the women is almost entirely of cotton, manufactured by themselves, except the richer class, and even many of these wear a great deal of homespun cotton. It is as well manufactured as the calicoes of Europe (Earle, 1898, p. 207).

In the Old World, the earliest evidence of cotton was found on the subcontinent of India, 8,000 years ago (Wikipedia, *Cotton*, 2016). India has had a continuous history of cotton from that time. People wove cotton for clothing throughout the country and used the cloth for trading (Boyle, 2010). Evidence for other cotton sites was Persia (Iran), 2,500 years ago, and Egypt, 5,000 years ago (Wikipedia, *Cotton*, 2016). There is very little recorded history about cotton in these areas until 1300 CE in Iran. Egypt, known for linen, did grow cotton but the dates for cotton used as clothing are vague until much later.

Cotton was unknown in Europe until Alexander the Great (356 BCE - 323 BCE) established trade routes from the east to west that brought cotton and cotton goods to the western world (Lee & Fang, 2015, p. 14). The Europeans saw cotton cloth and perhaps some saw the cotton lint — called plant wool at that time. However, they never saw the plant. This resulted in some fanciful ideas of what the cotton plant
might look like and that it might change into other beings (Mabey, 2015, p. 122). The
*Travels of Sir John Mandeville* was widely read in 1357 – 1371 CE (Wikipedia, 2016).

In the Middle Ages, in India and Pakistan where cotton was grown, almost all of
the manufacturing of cotton was done at home, (Beckert, 2014, p. 15). Some spinners and
weavers were selling their work. Merchants provided cotton or yarn to be spun and
woven in homes. The merchants would then buy the woven cloth or hand spun yarn
directly from them to sell in the markets. These spinners and weavers were independent
workers, using their own tools and working when they wished (Beckert, 2014, p. 34). In a
few areas, there were cotton workshops where the spinners and weavers would come
from the countryside to work at the shops for wages.

These systems of working from the home or close to the home continued as new
technologies, such as the treadle spinning wheel, the horizontal treadle loom and later the
flyer for the spinning wheel were created and spread across Europe. In the 1700s,
innovations came even faster – the flying shuttle, the spinning jenny, the spinning mule,
the spinning frame powered by water, the cotton gin and its many improvements and
finally the cotton mills that could do all of the ginning, spinning and weaving in one
factory. Cotton became a global commodity and ultimately, the fiber most used for
clothing throughout the world (Yafa, 2005, p. 2).

Today, cotton has multiple uses – more than any other fiber. In addition to
clothing, cotton is used in sewing thread, rope, tents, bookbinding, fishnets, bandages,
sutures, fire hoses, paper, and money. The little bits of fiber still attached to the cotton
seed, called linters, is used in dynamite, fingernail polish, sausage casings, linoleum,
cellophane, plastics, rocket fuel, thickening for ice cream, makeup and chewing gum.
Cottonseed oil is in margarine, salad dressing, potato chips and more. Cottonseed meal is used for cattle and fertilizer. (Thompson, 1994, p. 66-69).

**THE SCIENCE OF COTTON**

**Taxonomy:** The cotton plant belongs in the family Malvaceae. Hibiscus, okra and mallows are also in this family (Fox, 1987, p. 29). The family is divided into two tribes-Hibisceae and Gossypieae (Fryxell, 1979, p. 17). The tribe Gossypieae contains the genus *Gossypium*. All cottons are in the genus *Gossypium* (Fryxell, 1979, p.41).

**Genetics:** The two Old World cottons, *Gossypium arboreum* and *Gossypium herbaceum*, are diploid. They have one pair with 13 chromosomes each, for a total of 26 chromosomes. The New World cottons, *Gossypium hirsutum* and *Gossypium barbadense*, are tetraploid. They have two pairs with 13 chromosomes each, for a total of 52 chromosomes (Zhang & Endrizzi, 2015, p. 129).

In 1996, genetic engineering was introduced to cotton. Initially, the aim was to increase pest resistance and reduce the amount of pesticides sprayed on cotton fields. Weed resistance soon followed, along with increased cotton crop production (Zhang, 2015, p. 232). Reducing pesticides, herbicides and improving the quality of cotton has been successful. The primary disadvantage is some pests have become resistant to the modified cotton (Wikipedia (2016). *Bt Cotton*). There are many controversies around genetic engineering, especially with food crops. The result has been a significant increase in organic food and organic cotton.

**Chemical Composition:** The chemical composition of cotton is: cellulose 91%, water 7.85%, protoplasm and pectin 0.55%, waxes and fatty substances 0.4%, minerals salts 0.2% (Wikipedia, *Cotton*, 2016). There are some variations to these percentages.
Olvey, a cotton researcher and grower, states that the natural green colored cotton can have up to 15% waxes (personal communication, 2016).

**Climates:** Cotton can grow in long or short seasons -150 days to 100 days from planting to harvest, depending on genetic predisposition and the availability of water (Conaty, et al, 2015, p. 402). In temperate climates where temperatures fall below freezing, cotton can only be grown as an annual (Hochberg, 1979, p. 17). In the tropical climates, *Gossypium barbadense* can grow into a large bush where the cotton can be harvested year around for up to six years (Teague, 1998, p. 18).

Cotton grows in tropical and temperate climates between the 45° north latitude and the 36° south latitude (Conaty, et al, 2015, p. 402). The world map (Figure 3) shows the latitude lines at 40° (near 45°) north and 40° (near 36°) south. Cotton circles the globe.

**Biology:** Cotton begins with a cotton seed planted in soil. With sufficient warmth and moisture, the seed germinates within a few hours. Seedlings emerge above the soil in five to ten days. In four to five weeks, squares will appear. Squares are floral buds where
flowers will develop in approximately three weeks (Snider & Oosterhuis, 2015, p. 369.)

Cotton flowers are lovely but they have a short life, flowering white (or yellow if Pima) in the morning, turning red over the day, and withering at night. There is barely enough time for pollination, so they can self-pollinate. When the flower dies, the boll (also known as the fruit) takes its place (100% cotton, n.d.). Within the boll, now pollinated, ovules develop. These become seeds. The cotton fibers develop from the outer seed coat. Each fiber is a single cell. The cell begins to elongate, then it thickens. In 40-60 days the fibers mature and the boll opens (Snider & Oosterhuis, 2015, p. 375). There may be as many as 500,000 fibers in a single boll (100% cotton, n.d.).

**Fiber Development:** The cotton fiber starts with a thin cell wall, mostly cellulose and a central canal filled with protoplasm. The fiber elongates, while another layer of cellulose is added in a winding fashion. This is followed by a secondary wall of concentric layers of cellulose, thickening the wall, while the fiber continues to elongate. A cuticle covers the cellulose layers with an outer waxy layer that protects the fiber. The fiber matures
when the boll opens and the fibers dry. The protoplasm in the canal of the fiber dries and the lumen collapses making the fiber a flat ribbon. The ribbon twists and turns 50-100 convolutions per inch (Cotton Incorporated, 2016). These wonderful tiny twists and turns, are what make cotton spinnable (Figure 7).

**Cultivating and Domestication:** The very first cotton growers in ancient times began to change the cotton plant – adapting it to different environments, carrying it over long distances, adding to its diversity, ultimately altering the biological history of cotton (Beckert, 2014, p. 21). This has not changed – cotton growers are still striving for the highest quality of cotton fiber by selecting the best seeds, cross breeding, and genetically altering cotton to adapt to different climates, to tolerate less water, and to develop resistance to pests.

**Chemistry:** Gossypol is a substance (a terpenoid aldehyde pigment with other chemicals) found in tiny glands throughout all plants in the Gossypieae tribe (Fryxell, 1979, p. 203). It occurs in the leaves, stems, pod and seeds of the plant. Gossypol is toxic to humans and all nonruminate animals if ingested. Much of the toxin is destroyed during the crushing and heat processing done in the commercial preparation of cottonseed oil. Then the oil is safe for human consumption. After the oil is extracted the meal, high in protein, can be used safely for most animals except pigs and chickens (Porcher & Fick, 2005, p. 40). Some cotton has been genetically altered to remove the gossypol glands to make the cottonseed safe for food products, but this decreases the plant’s resistance to pests (Fryxell, 1979, p. 205). A research team has genetically engineered cotton plants
that contain very little gossypol in the seed, but still has the compound in the stems and leaves. This leaves the protection against non-seed pests and diseases and allows the seed to be used for oil and high quality meal for human consumption (Wikipedia, Gossypol, 2016).

**Cotton Classing:** Before modern machines, cotton grading was done by cotton classers. The classers evaluated cotton from the bales to determine its color, staple length, trash content, cleanliness and fineness by eye and touch. Their purpose was to grade the bale of cotton in order to determine its value and thus its price in the cotton market. There were nine grades with middling fair – the very best, down to good ordinary (Yafa, 2005, p. 195). These terms have persisted although rarely used now. In 1907, the cotton industry passed standards for uniform cotton grading to “…eliminate price differences between markets, provide a means of settling disputes, make the farmer more cognizant of the value of his product, and, therefore, put him in a better bargaining position, and in general be of great benefit to the cotton trade.” (Cotton, Inc., Classification of Cotton, 2016). Laws were passed to develop cotton grade standards and offer cotton classification services by the U.S. Department of Agriculture. Classing is optional. Most cotton farmers want the official classing because they can get more money for their cotton as well as improve their crops. Two samples, four ounces each, are removed from the bale and sent to the Cotton Classing office. High-volume instruments (HVI) are used to measure the fiber length, length uniformity, fiber strength, and micronaire (fineness). The color (the whiteness) of the cotton is also graded by HVI for Upland and Acala cotton. Only the classifications for extraneous matter and special conditions are still performed manually
such as the color for Pima cotton. Presently it is still graded by highly trained cotton classers rather than by machine. (Cotton, Inc., 2016).

**TYPES OF COTTON**

One of the New World cottons, *Gossypium hirsutum*, often called Upland, is now 90% of all commercial cotton grown around the world (Teresinha, 2016). Years of breeding along with genetic modifications have resulted in four current types of commercial *Gossypium hirsutum*: Acala, Delta, Plains, and Eastern xi. Delta cotton is used primarily in the southern states of the United States. Acala is the primary cotton used in the far west of the United States as it thrives in the dry heat and lower rainfall. (Supima, 2016). In the driest areas, Acala cotton fields require some irrigation.

*Gossypium hirsutum v. punctatum* subv *Sacaton* is similar to a type of cotton that was grown in Arizona and New Mexico in ancient times. It was known as Hopi cotton. Dean (2016, p. 62), an archaeologist, has examined many archaeological specimens of this ancient cotton and found all of them had lint that separated easily from the seeds. This is unusual as most cotton from *Gossypium hirsutum* has fuzzy seeds (also known as green seeds) where the lint is firmly attached to the seeds. Fortunately, the Native Americans in Arizona and New Mexico have continued to cultivate small amounts of this naked seed cotton (also called black seed) into the present day. To preserve this cotton type, seeds were gathered from the local Native Americans. These seeds are available through Native Seed/SEARCH with the name Sacaton Aboriginal.

*Gossypium barbadense*, the other New World cotton, has a different story. This cotton grew in northern South America, the islands in the West Indies and some areas in Mesoamerica. Wild *Gossypium hirsutum* grew on some of these areas as well and it was
believed that some were crossed with *Gossypium barbadense* by the natives before Columbus (Porcher & Fick, 2005, p.75). When settlers came, they found some cotton that was short and coarse as well as the long stapled cotton. Planters in the state of Georgia, in the United States, began experimenting with the long stapled cotton from the islands by selecting seeds from bolls that matured early; then planting them for the next year. Their hope was to create plants that matured early with most of the bolls opening at the same time for a viable commercial crop (Porcher & Fick, 2005, p. 93). After a mild winter in 1786 they succeeded. Sea Island cotton became a valued commercial crop. Cotton plantations flourished in the islands along Florida, Georgia and South Carolina. Sea Island cotton was a major export until 1920 when boll weevils destroyed the crops. According to Porcher and Fick (2005, p. xvii), Sea Island cotton was the finest cotton ever grown.

The story of Pima cotton began when scientific cotton breeding started in the United States in 1898. Over 450 seeds and plants were acquired by the Fairchild and Lathrop expedition in 1900-1901. Some of the Egyptian seeds from the expedition, previously crossed with Sea Island, were sent to Arizona and California. In 1902, Thomas H. Kearney, a plant scientist from the United States Department of Agriculture and others, began experimenting with these seeds in Arizona. In 1907, the Department of Agriculture created an experimental farm to grow cotton on the Pima Indian Reservation at Sacatont. Additional experimental farms around Arizona were added. In 1910, Kearney discovered a cotton plant in the experimental fields in Yuma, Arizona, that had a distinctly better fiber than all the previous ones. The seed from this cotton was cultivated on the Pima Indian Reservation at Sacaton– the only cultivar of *Gossypium barbadense*
grown in Arizona. The cotton was named Pima for the Pima people (now known as Akimel O’odham) who planted, tended and harvested the experimental crop. Pima became a generic term for all extra-long staple cotton around the world (Menke, Yoklic, & Jensen, 2002, pp. 4-8).

Not all cottons are white. In ancient times, cottons varied in colors from deep reddish brown through shades of brown, green, to pure white (Fryxell, 1979, p. 126). The colored cottons have persisted into the present day especially in Peru (Ecobutterfly, 2012). These colored cottons are becoming more popular with hand spinners. One initial drawback was that many of the colored cottons had very short fibers and often the fibers were coarse. Sally Fox was the first to hybridize and cultivate the naturally colored cottons in the United States. She noted that the colored cottons are more insect and disease resistant and more tolerant in drought (Fox, 1987, p. 30). Using breeding and careful selections she has improved the staple length and fineness of the colored cotton for easier spinning for hand spinners and commercial mills (Fox, 1987, p. 31). Today there are farmers and researchers working with colored cottons in Arizona, New Mexico, California and Texas.

*Gossypium thurberi* is a cotton with some unusual aspects. It is unique to the Sonoran Desert in southern Arizona. The climate in the Sonoran Desert is temperate with severe freezes in the winter. *Gossypium thurberi* has developed adaptations to this weather. It goes dormant before a frost; it can withstand lower temperatures unusual for this genus; and it can complete its cycle before the next frost (Fryxell, 1979, p. 150). As with many wild cottons, *Gossypium thurberi* is almost lint-less. According to Cotton Clouds, (personal communication, 2016), a decade ago a small patch of this cotton was grown in the Gila Valley of Arizona. It was hand-tended and hand-picked. Then it was
commercially ginned. The color is deep reddish brown with a very short staple - ¼ inch.
It is very unlikely that this is *Gossypium thurberi*, but this colored cotton is a lovely color
and it is representative of the extreme variations in the staple lengths of cottons.

**Characteristics and Properties of Cotton**

Characteristics and properties are very similar. The characteristics of cotton can be identified using sight, touch, and observation.

Table 1   General Characteristics of Cotton

<table>
<thead>
<tr>
<th>Soft to touch</th>
<th>Comfortable to wear</th>
<th>Hypoallergenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conducts heat</td>
<td>Cool in summer</td>
<td>Wicks moisture away from skin</td>
</tr>
<tr>
<td>Absorbs 27 times its weight in water</td>
<td>Stronger when wet</td>
<td>Machine washable</td>
</tr>
<tr>
<td>Does not produce static</td>
<td>Drapes well</td>
<td>Minimal elasticity</td>
</tr>
<tr>
<td>Dyes easily</td>
<td>Good durability</td>
<td>Resistant to alkali</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Damaged by acids</td>
</tr>
<tr>
<td>Resistant to moths</td>
<td>Can mildew</td>
<td>Damaged by silverfish</td>
</tr>
<tr>
<td>Burns readily</td>
<td>Wrinkles easily in fabric</td>
<td>Oxidizes in the sun</td>
</tr>
<tr>
<td></td>
<td></td>
<td>damaging fibers</td>
</tr>
</tbody>
</table>


The measured properties of cotton are done by machine. These are very important to the spinning mills. Short or long fibers require adjustments in the spinning machines. Weak fibers or too fine fibers will cause the machines to clog and breakdown. Fibers with many different lengths will cause nepsts that tangle in the machines (From a personal tour of a cotton research facility with gins, spinning and weaving machines, 2011). This happens with hand spinners as well although the hand spinner can remove nepsts as they occur. The hand spinner can also spin yarns that are too fine for the machines and spin weaker fibers without causing multiple breaks.
Table 2  Properties of Cotton Measured by HVI (High Volume Instrument)

<table>
<thead>
<tr>
<th>Length of Fiber</th>
<th>Short</th>
<th>Medium</th>
<th>Long</th>
<th>Extra Long</th>
<th>Average staple length of the fiber. Measured in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Below 0.99</td>
<td>0.99 – 1.10</td>
<td>1.11 – 1.26</td>
<td>Above 1.26</td>
<td></td>
</tr>
<tr>
<td>Uniformity of Fibers</td>
<td>Very Low</td>
<td>Low</td>
<td>Average</td>
<td>High</td>
<td>Measures the number of fibers with similar lengths. Too many short lengths will interfere with commercial spinning.</td>
</tr>
<tr>
<td></td>
<td>Below 77</td>
<td>77-79</td>
<td>80-82</td>
<td>83-85</td>
<td></td>
</tr>
<tr>
<td>Fiber Fineness (Called Micronaire)</td>
<td>Discount 3.4 or lower</td>
<td>Base 3.5-3.6</td>
<td>Premium 3.7-4.2</td>
<td>Base 4.3-4.9</td>
<td>Measures the fineness and maturity of a fiber. Measured with 2.34 gms of cotton compressed into a consistent space and air permeability.</td>
</tr>
<tr>
<td></td>
<td>Discount 23 and below</td>
<td>Intermediate 24-25</td>
<td>Average 26-28</td>
<td>Strong 29-30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>23 and above</td>
<td>24-25</td>
<td>26-28</td>
<td>29-30</td>
<td></td>
</tr>
<tr>
<td>Fiber Strength</td>
<td>Very Strong</td>
<td>31 and above</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


**GINNING COTTON**

Ginning or to gin is a term commonly used as the process of removing seed from cotton. The word gin is believed to be a contraction of the word engine (Hughes & Holt, 2015, p. 609). Perhaps gin was first applied to Eli Whitney’s gin in 1793. However it came about, everything today related to removing seeds from cotton is called ginning.

The earliest way to gin cotton was finger ginning (Figure 8). It is still in use today. First, the seed cotton is held in the non-dominant hand. Then using the thumb and forefinger, the lint is pulled off the mass of seed cotton with a quick repetitive motion. As the seeds are clear of the lint, they can be dropped to one side. It takes 12 or more hours to finger gin a pound of cotton. Generally, the seeds are approximately $2/3$ the weight of a pound of cotton.
To test this generalization, I did an experiment using a digital pocket scale with the lowest measurement of 0.1 gram. Acala seed cotton was weighed to 30 grams. Then the seeds were removed by finger ginning. This required 37 minutes to separate the lint from the seeds. The seeds weighed 17.8 grams. The lint weighed 12 grams. The loss of 0.2 grams is due to the debris that fell out of the cotton during finger ginning. The result:

The seeds weighed 2 gms less than the usual $\frac{2}{3}$ weight for the seeds. This may be due to the longer staple of Acala cotton as well as a higher proportion of lint. The experiment was repeated with the Sacaton Aboriginal cotton with these results: Seeds weighed 24 grams, lint weighed 6 grams. The Sacaton Aboriginal cotton has a shorter staple length and less lint therefore a higher weight (4 gms more) for the seeds then the $\frac{2}{3}$ standard.

A different way of ginning cotton was reported by Kent, an archeological textile analyst (1983, p. 29), used by the modern Hopi in Arizona. The seed cotton was placed on half of a blanket. The blanket was then folded, covering the cotton. Using a three-prong switch, they beat upon the blanket to make the seeds fall out of the cotton and the lint to adhere to the blanket making a lap or batt ready for spinning.

I recreated this technique to determine if it worked as easily as suggested. Using Sacaton Aboriginal cotton and a cotton blanket, the cotton was beaten with the three-prong switch noted in the Figure 9.

\[1\] Note: Starting with Figure 8, all photographs from this point are by the author unless otherwise credited.
Here the seed cotton clung together and adhered on one side of the blanket. The black specks are cotton seeds. The seeds were loosened and they were easily picked out of the lint, but they did not fall out of the cotton. The lint left a few fibers on the blanket but nothing that could be considered a batt. I repeated this technique with a wool blanket and the result was the same. It is possible that using a thin wool blanket might work. I am skeptical that this technique was used on a regular basis.

The earliest gin is the single roller gin, first noted in 500 CE and purportedly still in use in the twentieth century in Asia, Africa and the American Southwest (Lakwete, 2003, p. 3). The single roller gin (Figure 10) worked similarly to grinding wheat, except the idea was not to crush the seeds. The seeds are squeezed forward of the roller, leaving the lint behind. The roller requires a flat smooth surface, usually a rock, flat on both sides. The roller has to be smooth, round and made of wood or iron. Lakwete (2003, p. 5) describes an iron roller no more than 5/8 inches in diameter in the middle and tapers off on each side so that the sides overhang the rock. One layer of seed cotton is spread in the center of the flat surface. The ginning is done by positioning the shoulders...
over the rock, and using short rolls with pressure on the lint. The seeds appear ahead of the roller. It is important not to crush the seeds as this will spoil the lint. Eventually the seeds can be picked out as they are freed from the lint. With a skilled operator, the single roller gin produced approximately one pound of ginned cotton a day — about the same amount of cotton and time as fingerginning.

The double-roller gin was the next improvement in ginning. It is dated approximately 1100 CE (Lakwete, 2008, p. 11). This gin has two rollers. There is a hand crank on the side. When the handle is turned, the rollers go in opposite directions, driven by gears. The cotton is pulled through the rollers, leaving the seeds behind. This gin could produce five pounds of lint in a day (Porcher & Fick, 2005, p. 187). The churka gin, Figure 11, is a double-roller gin from India. The churka gin was noted by several authors as the best of the double-roller gins (Lakwete, 2003, p. 15; Porcher & Fick, 2005, P. 190).

There were many variations and improvements to the double-roller gin making them larger, adding treadles and more power using people, animals and steam (Porcher & Fick, 2005, pp. 192 – 217). The Sea Island cotton plantation system thrived with the double-roller gin, reaching a zenith with the Foss double-roller steam powered gin that could gin 2,200 pounds of cotton a day (Porcher & Fick, 2005, p. 188). The naked seeds
of the extra-long stapled *Gossypium barbadense* slide away from the lint with the double-roller gins, making the ginning process much easier. These gins also handle the long stapled cotton better with fewer breaks and neps, and they provide cleaner lint (Porcher & Fick, 2005, p. 186). There are very few gins now in the United States that use the double-roller gins for the extra-long stapled cotton.

The double-roller gins were used for the fuzzy seed cotton, *Gossypium hirsutum*, but with less success. The fuzzy seeds hang onto the lint, decreasing the efficacy of the roller gin. This type of cotton, *Gossypium hirsutum*, grew well on the southern plantations but the ginning process prevented it from becoming a major crop until the saw gin was invented. In 1793, before Eli Whitney created the cotton gin, the American southeast exported 487,000 pounds of cotton. The following year with Eli Whitney’s gin, they exported 1.6 million pounds of cotton (Yafa, 2005, p.86).

Eli Whitney’s original gin was a spike tooth gin. Hodgen Holmes made the adjustment to the saw blade that is still in use today (Hughes & Holt, 2015, p. 636). The saw blades are placed in a line across the front of the gin. A series of slits cover the blades, but allow the teeth of the blades to come through the slits. When seed cotton is put on top of the slits and the crank is turned, the teeth pull the cotton through the slits. The seeds are too large to go through
the slits so they fall down in front of the gin. There are brushes in the back of the gin, behind the saw blades, that collect the lint. Many improvements have been made on the cotton gin since 1793. All are a variation on saw gins.

The commercial gins (Figure 13) are run by machine, monitored by technicians. The compacted seed cotton from the fields is delivered to the gin by trucks in modules. The modules resemble bales but they are much larger - the equivalent of 3-16 bales (Hughes & Holt, 2015, p. 620). At the gin, the seed cotton is vacuumed up from the module into the conduits inside the gin. From there, the cotton is blown to the ginning machine. The seed cotton flows down to the saw blades where the lint can be pulled into the gin by the saw teeth. The seeds drop in front of the blades where they are collected for further processing into linters, cottonseed oil and cottonseed meal. The lint then goes through another conduit to the compressor/baler machine.

Large cotton gins may have three or more commercial ginning machines. These machines can gin, collect seed, clean the lint, remove debris and bale the cotton. The high capacity gins can bale 30 bales an hour, each weighing approximately five hundred pounds (Hughes & Holt, 2015, p. 636).

Commercial cotton is white as it is easier to dye then the naturally colored cottons. Many gins will not accept colored cotton. The few gins willing to gin these
cottons will wait until all of the white cotton has been ginned. The colored cottons are ginned last. Then the machines are cleaned and ready for the next white crop in the fall.

**PREPARING COTTON FOR SPINNING**

Since the revival of hand spinning in the 1970's, modern day spinners have experimented with various ways of preparing fibers for spinning. Wool was generally the first fiber used, then various other animal fibers and finally plant fibers including cotton. Linder and Linder (1977) brought cotton to hand spinners in the United States through teaching and writing their book, *Hand Spinning Cotton*.

**Modern Methods of Preparing Cotton for Spinning:** Baling cotton is the first commercial step toward preparing cotton for spinning. Commercial cotton is baled for shipping and storage. For some spinners baled cotton is their first sight of raw cotton. The process starts with layers of cotton blown into the baler straight from the gin. A huge compactor compresses the cotton into a dense bale approximately three feet by five feet and weighing about 480 pounds.

The cotton expands after the bale is opened but the remaining compaction prevents easy drafting. Spinning cotton at this stage will create a textured yarn that can be attractive, although the thick and thin areas in the yarn can break easily.

Spinners can open the cotton further for easier spinning by steaming. One method is to place no more than an ounce of cotton in a colander over boiling water for an hour,
turning the cotton over every 15 minutes without squeezing. Another method is to put the ginned cotton in a mesh bag and hang it in the shower for several hours. The cotton should be completely dry before spinning. These methods decompress the cotton but not completely. Usually there will be neps and bits of the plants in baled cotton. Normally, this is removed in the mills. Some of the trash will fall out during spinning.

Cotton sliver is machine prepared in cotton mills. The process begins by blowing the cotton through multiple conduits with temperature controlled heat and moisture. This cleans the cotton and the debris and dirt falls out. Then, the cotton is carded and then combed before it goes into the spinning machines. The combing stretches the cotton, making it thinner, straighter and more uniform for the weaving machines. Combed cotton has a slippery feel and a slight sheen as noted in the shiny white cotton, Figure 15. This slippery, silk-like quality can make it difficult to maintain an even tension and consistent grist for the hand spinner. A few mills will produce carded cotton sliver that is available for spinners. All of the other cottons noted in the photo above are carded sliver. Many spinners believe the carded cotton sliver is much easier to spin than combed cotton.

**Ancient Methods of Preparing Cotton for Spinning:** Searching for the ancient cotton preparation techniques has been much more difficult. Much has been lost to industrialization. Fortunately a few cultures in rural areas have preserved their textile
traditions including the preparation of cotton. Books and internet searches have yielded enough information to reproduce some of the ancient techniques for preparing cotton.

**Bowing to Prepare Cotton for Spinning:** Evidence suggests this is an Old World technique from India, Asia and possibly the Middle East. There are some areas in the American Southwest that report bowing after the Spanish came in the 16th century.

To prepare for bowing, the seeds are removed with a roller gin or by finger ginning. Then the lint is placed in a basket or on a table. The bow used for this technique is similar to bows that are used for hunting with arrows. The bows vary in appearance but the function is the same to all. It is the taut string that does the work. Plucking the string in contact with the cotton causes a vibration that induces air into the mass of cotton fibers. This opens and separates the fibers so that the mass becomes fluffy. After bowing, the mass of lint will appear to be two times or more its previous size. One of the benefits of bowing is the removal of the bits of plant debris that fall out during the process. This cleans the cotton some and decreases the frequency of picking out debris and neps while spinning. In some cultures, when bowing is done, the cotton is spun without any further preparations (Wild Films India, 2015).
In other cultures, such as the Lue, Laos, and Li, in Asia and China, after the cotton has been bowed, it is rolled on a stick into a thick, tight puni (Whittlesey, 2010; Sayabouly Cotton, 2010; UNESCO, 2009). This thick puni (Figure 17) works very well for spinning cotton. Although it is compacted, the fiber drafts easily and creates a fine, consistent thread with minimal slubs.

**Beating to Prepare Cotton for Spinning:** In the New World, the primary ancient technique for preparing cotton was to beat the cotton with switches or sticks. This technique has continued in Ecuador and Mexico in rural areas with grandparents and parents teaching their children and passing on their traditions of spinning and weaving. Modern day Hopi and Puebloans in Arizona and New Mexico are currently reviving their ancestors’ way of beating to prepare cotton for spinning and weaving.

Before beating, the cotton the seeds are removed, usually by finger ginning. To prepare for beating, a stiff pillow or a rolled bale of hay can be used. This should not be a hard surface but a firm one that allows for some resilience. The pillow or small bale is covered by a mat or rug and then the cotton lint is put on top. There are two types of beating: one with switches and one with sticks (Figure 18 & 19).

For beating with a switch or switches, three to five pronged switches are used, either one switch in each hand or just in one hand. Pronged sticks are also used. Beating with the pronged switches makes the cotton lofty. The beating also removes trash.
Beating with Switches

Beating is repetitive and can be tiring. It is not easy to know when to stop. The cotton fibers should separate; there should be fewer dense areas and finally the cotton should look homogenous. Beating with switches makes a lap that is light and loosely held together. Once it is beaten, the lap is usually folded with each side to the center to make a long rectangle. Then, it is gently rolled into a soft, loose ball to store or to spin (Casa Flor Ixaco, 2015).

The second technique is beating with a stick. The stick should be thick - ¼ inch to ¾ inch (approximately 1 to 2 centimeters) in diameter. One stick in one hand can be used or a stick in each hand. Beating with a stick removes trash but does not fluff the cotton. Instead the cotton is compacted. More cotton can be used with the sticks than with the switches. The lap is thicker and becomes homogenous sooner. During beating, the lap is usually manipulated to create a rectangle. To shape the lap evenly, bits of cotton that fly off during beating are put back into the lap. The edges are controlled by rolling them into the lap or pulling off stray areas on the edges and putting them into any thin areas. In some cultures the lap is placed on a distaff and spun from there, pulling the
lap forward as needed to continue spinning (Klumpp, 2013). In other cultures, the cotton lap is rolled into a ball. Spun from the ball, it is unrolled as needed to continue spinning (Handspinning and Weaving Brown Cotton in Coastal Oxaca, 2014).

**Carding:** The origins of hand carders are difficult to find. Most references start in the 1700’s in England. Daniel Defoe noted women and children carding in their homes in 1724. Edward Baines recorded how cotton carders were made with brushes of short pieces of wire imbedded into leather and fastened to a piece of wood in 1835 (Simkin, 2015), very similar to modern day hand cards.

Carders were not used in North America until the Europeans came. It was a highly valued tool. Women migrating to the Texas frontier in the 1800’s took carders with them. These families planted cotton for home use. The women spun and wove to clothe their family. During the American Civil War (1861-1865), food and clothing in Texas were difficult to obtain; “women became aggressive … stopping the government wagon and confiscating … cotton [and carders] … under protest from the drivers” (Marks, 1996).

Carding aligns and separates the fibers and sheds some of the trash that comes with commercially ginned cotton. Any carder can be used, but the carder with fine teeth (110 points per square inch or more) provides the best results for cotton. The card is charged with fiber from the heel of the card (just below the teeth), to the
toe. The teeth curve toward the heel. It works best to start charging just below the teeth at the heel. This prevents loops forming around the teeth at the top of the heel and keeps the fibers straight. The sides are left free of cotton for an inch or more, when charging the cards as the cotton spreads during carding. The teeth should lightly touch when carding. Too much pressure or enmeshing of the teeth buries the cotton into the carder.

To card, gently brush the cotton starting at the toe. For each pass, brush completely off the cards until the fiber at the toe is clear. Otherwise the fiber will bunch together and tangle. For each succeeding pass, move up in small increments until the entire card is brushed. Then brush across the entire card several times until the cotton is evenly distributed. When the cotton fibers are aligned and even across the card, they can be transferred to the other card. To create more texture, use fewer passes and less carding.

To transfer, both cards are positioned with the heel up. The toe of the card on top is at the heel of the bottom card. Place the top card where the wisps are coming off the toe of the top card, at the teeth of the heel of the bottom card. Catch the wisps onto the teeth at the heel of the bottom card. By moving the top card down and the bottom card up, in a fluid motion (not engaging the teeth) the batt is lifted off the teeth.
Then resume carding. After several strokes, the transfer is made with the other card with the same motions (Ruane, 2012). When carding is completed, the batt can be transferred off each card separately, treating each batt individually or transferred off one card, then off the second card on top of the first, treating the two batts as one. The batts are then rolled into a rolag, rolling from the toe of the card to the heel. Rolags have been the standard for the final preparation for spinning since hand cards came to the Americas. Wool and other animal fibers were also carded and made into rolags.

The puni likely originated in India. It is similar to a rolag, but the puni makes the cotton slightly compacted and easy to spin. To make a puni, start with a hand carder and follow the same directions as for a rolag. When the carding is finished and the final batt is transferred, use a small dowel (\( \frac{3}{8} \) to \( \frac{1}{4} \) diameter) placed across the cotton at the toe of the carder. Gently smooth the cotton around the dowel and then roll the dowel with the cotton to the heel of the carder. For a tighter puni, continue to roll the stick to the end of the heel of the card. Then roll off the teeth, but stay on the card just under the teeth. The dowel will fit in that space. A few more rolls under the teeth will tighten the puni.
SPECIFICS FOR SAMPLES OF HANDSPUN YARNS

The cottons for this study were gathered from fiber shows, fiber shops, local spinners and local cotton growers. The staple length, wraps per inch, twists per inch, twist angle and the Bradford count were measured for each plied cotton sample. The singles were measured for wraps per inch only.

I determined the staple length by lining up the cotton fibers and removing the shorter fibers to leave the longest fibers. These fibers were measured with a ruler. The staple lengths of the cottons in this study vary from ¼ to 1 ¾ inches.

WPI (wraps per inch) is a way of determining the diameter or grist of a yarn. This was measured by wrapping the yarn around a ruler without tension. Each strand was wrapped closely to the previous strand, covering the ruler for one inch. Then the strands were counted. If the yarn wrapped around the ruler eight times in one inch the diameter of one strand of yarn is approximately $\frac{1}{8}$ inch in diameter. The WPI would be eight.

The TPI (twists per inch) was measured for the plied yarns. This was done by counting the bumps on the yarn, then dividing by the number of plies. For example, if the yarn is 2-ply and there are ten bumps in one inch of yarn, then the tpi would be five. The tpi and twist angle in a plied yarn suggests the softness or firmness of the yarn.

The angle of twist was determined by using a protractor. The yarn was laid on the protractor at 0. Keeping the yarn straight, it was moved across the various angles until the twist angle in the yarn matched an angle on the angle ruler. This works best for plied yarns. For my plied sample yarns, the angle varies from $15^0$ to $25^0$. 
The Bradford count was used to determine the commercial sizes of the yarn and the number of yards per pound. A more thorough explanation of this is given in the Appendix.

For all samples, a small amount of the raw and/or prepared cotton fiber is included along with the handspun yarns. For spinning off the seed samples, a few cotton seeds are also included. All yarns are spun Z (clockwise) and plied S (counterclockwise). Most of the samples are plied yarns. Singles are included for comparison with the plied yarns and for the different preparations.

**TOOLS AND TECHNIQUES FOR SPINNING COTTON**

I chose the tools for the specific spinning techniques based on the different preparations of cotton used in this study. The ancient tools, i.e., the spindles, were used for spinning the ancient preparations of cotton that required finger ginning. Hand carders and the spinning wheel were used for the modern commercial preparations of cotton that include the commercially ginned cotton and cotton slivers.

The spindles in Figure 25 are the ones I used for spinning the re-created ancient and modern samples. The spindle on the far left has a whorl from an archeological site in Colombia, dated to 600 BCE. The shaft is modern. Although this spindle appears heavy, it is easy to spin even for the finest cotton thread. The spindle in the center is a re-creation of spindles that were common in many of the archaeological sites in Arizona (Teague, 1998, pp. 50, 54).
The shaft is from a bush called Mountain Mahogany used in ancient times for arrows and spindle shafts (information from Museum at Walnut Creek ruins in Arizona). The clay whorl was pit fired (made by Mary Snyder, personal friend and spinner) to make the spindle as accurate as possible. The spindle on the right is a Tahkli spindle. Similar spindles have been used in India since ancient times. The metal ones were imported to the United States in the 1970s. The thin metal shaft, sharp tip and balanced flat whorl allow them to spin very fast.

**Spinning with Support Spindles:**

Small support spindles work well for spinning cotton and other fine fibers. The bottom tip of the support spindle rests on the ground or in a bowl while spinning. Some cultures support the bottom tip between their toes.

First, a thread, called a leader, is tied to the shaft of the spindle. The leader can be finger or thigh-spun (Figure 26), or a commercial yarn. To spin, the leader is laid onto the cotton; then the spindle is twirled until the fiber catches. (1) With the fiber hand, the cotton is held lightly while pulling back from the spindle and watching the cotton fibers as they enter the triangle called the drafting zone (Figure 28). (2) With the spindle hand, the spindle is twirled to insert more twist into the fiber as needed without letting the twist pass beyond the drafting triangle.
Continue to draft, then spin while watching the drafting zone. Once the yarn is 10-12 inches long, spin the spindle a couple of times to add twist and then wind the yarn onto the spindle starting at the whorl. Repeat from (1).

Samples 1-3: Spinning off the Seed:

Spinning off the seed might have been an ancient technique, ginning and spinning the cotton at the same time instead of finger ginning the cotton first. It is popular today for learning to spin cotton and just for fun.

The technique does not require any preparation of the cotton for spinning. It works best with the long-stapled cottons such as Pima that have naked seeds (black seeds). Sacaton Aboriginal, a pre-Colombian race of the southwestern U.S, is a short-stapled cotton but also has naked seeds. Cotton comes off the naked seeds with minimal effort. Often a small bit of cotton clings to the seed, but is easily picked off.

Below are three samples of spinning off the seed with samples of fiber, seeds and handspun yarn. Acala was included as fuzzy seed cotton to determine if this technique is more difficult or time consuming with fuzzy seeds. The prehistoric Colombian support spindle was used for spinning and plying these three samples.
Spinning Off the Seed

Sample 1: Raw *Gossypium hirsutum* Acala Seed Cotton

Preparation None.

Spinning Technique: Hold one seed cotton in one hand. With the other hand, draft cotton from the seed and finger spin to begin a thread (Figure 26). Continue to finger or thigh-spin until there is a length of yarn long enough to wrap around the spindle shaft. Then proceed with (1) drafting off the seed, spinning Z and (2) wind on shaft. When as much of the fiber as possible has been spun from the seed, gently pull the seed off the yarn and join another seed with lint and continue spinning.

<table>
<thead>
<tr>
<th>Staple Length: 1 inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample of Acala seed cotton</td>
</tr>
<tr>
<td>Z Single yarn</td>
</tr>
<tr>
<td>WPI: 52</td>
</tr>
<tr>
<td>2-ply yarn zz/S</td>
</tr>
<tr>
<td>WPI: 31 TPI: 5</td>
</tr>
<tr>
<td>Twist Angle: 15° Count: 15/2</td>
</tr>
</tbody>
</table>

Comments: Spinning off the seed with Acala worked although there was some difficulty in pulling the last bit of lint off the seed. There did not seem to be much difference in the time required to spin with the Acala fuzzy seed versus either of the other two samples.
Sample 2: Raw *Gossypium barbadense* Pima Seed Cotton

Preparation None.

Spinning Technique: Same as Sample 1

<table>
<thead>
<tr>
<th>staple length: 1 ½ inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>sample of Pima seed cotton</td>
</tr>
<tr>
<td>Z single yarn</td>
</tr>
<tr>
<td>WPI: 56</td>
</tr>
<tr>
<td>2-ply yarn  zz/S</td>
</tr>
<tr>
<td>WPI: 34  TPI: 6  twist angle: 12°  count: 18/2</td>
</tr>
</tbody>
</table>

Comments: Spinning off the seed with Pima cotton seeds worked beautifully with the longer staple. A small portion of lint adhered to the bottom of the cotton seed. This bit comes off when pulled but often a small bit of the seed comes with it. Pima cotton is considered an ELS (Extra-long stapled) cotton.

This cotton was grown by a researcher in Mesa, AZ
Sample 3: Raw *Gossypium hirsutum* v. *punctatum* subv *Sacaton* Seed Cotton

Preparation: None.

Spinning Technique: Same as Sample 1

![Sample of Sacaton seed cotton](image)

<table>
<thead>
<tr>
<th>Staple Length: ¾ inch</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Sample of Sacaton seed cotton</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Z Single yarn</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>WPI: 52</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>2-ply yarn  zz/S</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>WPI: 33  TPI: 8  Twist Angle: 20°  Count: 15/2</th>
</tr>
</thead>
</table>

Comments: Sacaton Aboriginal cotton has a shorter staple length and there is less lint. Both Acala and Pima have long staples. The Sacaton has a soft touch and the seed is easily removed. Once spun it feels less soft than the Acala or Pima, but it is a strong yarn. This cotton was grown in northern New Mexico in a small cotton patch by Glenna Dean.
Samples 1-4: Spinning Commercially Ginned Cotton on Spindles and a Wheel

Spinning Cotton on a Spinning Wheel: With the modern spinning wheels available today, almost any wheel can be used for spinning cotton. However, the spinning wheels that work best are flyer-driven with a bobbin brake and have high ratio whorls. Flyer driven means the flyer goes around when the wheel is treadled. With the brake on the bobbin, the brake can be adjusted in small increments to control how fast the yarn goes in the orifice and onto the bobbin. High ratio whorls insert more twist each time the wheel goes around. A ratio of 12:1 or higher is best for spinning cotton on a spinning wheel.

I used the ratios of 12:1, 15:1 and 17:1 for spinning cotton. A ratio of 12:1 means with one full turn of the wheel, 12 twists go into a length of yarn. If one inch of yarn is held for one treadle of the wheel, then 12 twists will go into that one inch of yarn.

All of the yarns were spun as a long draw, point of contact. The twist enters the fibers at the tip of the drafting area while the fiber hand is moving back. I use my forward hand to create a brake in the yarn to slow the twist making drafting easier. This technique is perfect for short fibers and fast spinning whether on a wheel or spindle. Support spindles were used in the samples for the ginned cotton spun without further preparation. The carded samples were hand carded and spun on the Lendrum spinning wheel.
Table 4

**Sample 1: Gossypium hirsutum, Acala Cotton**

Preparation: There was no additional preparation for the singles yarn.

I decided to add a carded and plied yarn to compare the difference in preparations. This cotton was teased open then carded on cotton carders and rolled into a puni.

Spinning Technique: The ginned cotton was spun on a support spindle without teasing or any type of preparation for a single yarn.

The carded puni was spun on the Lendrum spinning wheel at a ratio of 17:1 When I had two singles, I plied them together (S), with the spinning wheel at a ratio of 15:1.

| Sample of Commercially Ginned Acala Cotton | WPI: 30  |
| Sample of Single Spun Ginned Acala Cotton without Preparation | TPI: 7  |
| Sample of Carded Puni | Twist Angle: 20°  |
| 2-ply yarn  | Count: 7.7/2  |

Comments: Acala is the primary cotton grown in the western portion of the United States. It is known as a long staple cotton. The ginned cotton for this sample is from Brookmoore Creations.
Sample 2: *Gossypium barbadense*, Sea Island

Preparation: Same as Sample 1.
The Sea Island ginned cotton was less compacted with almost no debris.

Spinning Technique: Same as Sample 1

<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample of Commercially Ginned Sea Island Cotton</td>
<td>Staple Length: 1(\frac{3}{4}) inches</td>
</tr>
<tr>
<td></td>
<td>Sample of Single Spun Ginned Sea Island Cotton without Preparation</td>
<td>WPI: 36</td>
</tr>
<tr>
<td></td>
<td>Sample of Carded Puni</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2-ply yarn zz/S</td>
<td>WPI: 30, TPI: 7, Twist Angle: 20°, Count: 9.8/2</td>
</tr>
</tbody>
</table>

Comments: The extra-long staple of the Sea Island cotton made it difficult to draft using the ginned cotton with the support spindle. There were more breaks and slubs in the single yarn due to this. It was much easier to spin with the carded puni on the spinning wheel.

This cotton also came from a researcher in Mesa, Arizona.
Sample 3: *Gossypium barbadense*, Pima

Preparation: Same as Sample 1
Spinning Technique: Same as Sample 1

<table>
<thead>
<tr>
<th>Sample of Commercially Ginned Pima Cotton</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Sample of Single Spun Ginned Pima Cotton without Preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td>WPI: 46 Note: the single was spun without preparation. The plied yarn was finer with the carded prep.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample of Carded Puni</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>2-ply yarn zz/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>WPI: 42 TPI: 7.5</td>
</tr>
<tr>
<td>Twist Angle: 20°</td>
</tr>
<tr>
<td>Count: 18/2</td>
</tr>
</tbody>
</table>

Comments: This cotton was obtained from the Cotton Classing Office in Phoenix, AZ. The Tucson Handweavers and Spinners Guild’s Spinning Study Group was able to tour the Cotton Classing Office on June 30, 2005. This cotton was from one of the samples removed from a bale for testing. The cotton was considered too fine and too weak for mills. However, handspinners can use it. The micronaire was 2.6. This ginned cotton was not matted or compacted like the other ginned cottons. It is unclear if the fineness of the fiber affected the cotton making it so soft and resistive to matting.
Sample 4: Cotton Clouds, Safford, AZ: *Gossypium*: species unknown

Preparation: Same as Sample 1.

The short staple length on this cotton created a problem with rolling the puni. It was difficult to get the cotton around the dowel.

Spinning Technique: Same as Sample 1.

<table>
<thead>
<tr>
<th>Staple Length: 5/8 inch</th>
</tr>
</thead>
</table>

Sample of Commercially Ginned Cotton

Sample of Single Spin Ginned Cotton without Preparation

WPI: 35

Sample of Carded Puni

2-ply yarn  zz/S

WPI: 24  TPI: 5  Twist Angle: 15°  Count: 7/2

Comments: The puni spun fairly easily despite the short fiber. This cotton came from Cotton Clouds in Safford, AZ at least 10 years ago. It was touted as *Gossypium thurberi*, a wild cotton that is almost lintless. The color is wonderful. The mystery is – is this *G. thurberi* maybe crossed with *G. hirsutum*? Olvey, a cotton researcher, (personal communication) suggests that “*G. thurberi* has a seed pod and is lintless but when intergraded [in a lab] with another cotton species can benefit in increased fiber quality”.
Samples 1-11: Spinning Commercially Prepared Cotton Sliver

The advantage of the commercial cotton sliver is that it is ready to spin. No additional preparation is needed. Many beginning cotton spinners start with cotton sliver. These eleven samples explore the variations in commercial cotton slivers. Cotton slivers are not alike as they are prepared by different machines. Cottons are different also. The samples provide a comparison between *Gossypium hirsutum* and *Gossypium barbadense*, and the differences within these types of cotton such as shorter staple lengths and finer fibers. Another problem is how the slivers have been stored. If compacted, the sliver may not draft easily causing slubs and thin spots. All slivers are directional – they spin best in one direction. Spinning in the wrong direction will cause a regular series of slubs and uneven grist, not to mention frustration. This is easily fixed by reversing the fiber and spinning from the opposite end. Keeping a hang tag or clip on the correct end of the unspun sliver is helpful.

**Table 5**  
**Sample 1: Fiber Factory, Mesa, AZ, Carded: Gossypium hirsutum**

Spinning Technique: Point of contact, long draw, spun ratio 15:1, plied ratio of 12:1

<table>
<thead>
<tr>
<th>Staple Length: 1 inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample of Commercial Brown Sliver</td>
</tr>
<tr>
<td>2- ply yarn zz/S</td>
</tr>
<tr>
<td>WPI: 24</td>
</tr>
<tr>
<td>Count: 5/2</td>
</tr>
</tbody>
</table>

Comment: nice, easy to spin.
Sample 2: Woodland Woolworks, Brown and White Swirl Cotton:  
*Gossypium hirsutum*

Spinning Technique: Same as Sample 1

<table>
<thead>
<tr>
<th>Staple Length: 1 ¼ inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample of Commercial Swirl Sliver</td>
</tr>
<tr>
<td>2-ply yarn zz/S</td>
</tr>
<tr>
<td>WPI: 17  TPI: 3.5</td>
</tr>
<tr>
<td>Twist Angle: 20°</td>
</tr>
<tr>
<td>Count: 3.4/2</td>
</tr>
</tbody>
</table>

Comments: The swirl cotton was more challenging due to the differences in the two slivers. The brown cotton was shorter; the white fiber feels silky. I think both of these slivers were combed. This added to the challenge in making a consistent yarn. It did make a nice textured cotton yarn.

Sample 3: Southwest Corners, McNeal, AZ, Carded, Sea Island:  
*Gossypium barbadense*

Spinning Technique: Same as Sample 1

<table>
<thead>
<tr>
<th>Staple Length: 1 ¾ inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample of Commercial Sliver-Sea Island</td>
</tr>
<tr>
<td>2-ply yarn zz/S</td>
</tr>
<tr>
<td>WPI: 23  TPI: 5</td>
</tr>
<tr>
<td>Twist angle: 20°</td>
</tr>
<tr>
<td>Count: 5.7/2</td>
</tr>
</tbody>
</table>

Comment: Silk easy to spin
**Sample 4: Brookmoore Creations, Tucson, AZ, Carded Acala: *Gossypium hirsutum***

Spinning Technique: Same as Sample 1.

<table>
<thead>
<tr>
<th>Staple Length: 1 ¼ inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample of Acala Commercial Sliver</td>
</tr>
<tr>
<td>2-ply yarn zz/S</td>
</tr>
<tr>
<td>WPI: 28 TPI: 5-6 Twist Angle: 15° Count: 12/2</td>
</tr>
</tbody>
</table>

Comments: Very nice and easy to spin. The sliver was clean without any debris.

**Sample 5: Ecobutterfly, Peru, Organic, Carded: *Gossypium hirsutum***

Spinning Technique: Same as Sample 1.

<table>
<thead>
<tr>
<th>Staple Length: 1 ¼ inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample of Commercial Brown Sliver</td>
</tr>
<tr>
<td>2-ply yarn zz/S</td>
</tr>
<tr>
<td>WPI: 25 TPI: 5 Twist angle: 15° Count: 7/2</td>
</tr>
</tbody>
</table>

Comment: The Ecobutterfly sliver was very soft. The sliver did not draft quite as well as others. There was some debris.
Sample 6: Brookmoore Creations, Tucson, AZ, Carded Pima: *Gossypium barbadense*

Spinning Technique: Same as Sample 1

<table>
<thead>
<tr>
<th>Staple Length: $1\ 5/8$ inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample of Pima Commercial Sliver</td>
</tr>
<tr>
<td>2-ply yarn zz/S</td>
</tr>
<tr>
<td>WPI: 27  TPI: 5  Twist Angle: 20°  Count: 7/2</td>
</tr>
</tbody>
</table>

Comments: Strong, soft and easy to spin from the sliver.

Sample 7: Brookmoore Creations, Combed Acala: *Gossypium hirsutum*

Spinning Technique: Same as Sample 1.

<table>
<thead>
<tr>
<th>Staple Length: $1\ 5/8$ inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample of Combed Acala Commercial Sliver</td>
</tr>
<tr>
<td>zz/S, 2-ply yarn</td>
</tr>
<tr>
<td>WPI: 23  TPI: 5  Twist angle: 15°  Count: 5.7/2</td>
</tr>
</tbody>
</table>

Comments: I had difficulty maintaining consistent grist with this combed Acala sliver. The yarn is uneven but might add a nice texture to a garment.
Sample 8: Brookmoore Creations, Carded, Natural Green: *Gossypium hirsutum*

Spinning Technique: Same as Sample 1.

| Staple Length: 1 inch |
| Sample of Commercial Green Sliver |
| 2-ply yarn zz/S |
| WPI: 17  TPI: 4 |
| Twist Angle: 15°  Count: 4/2 |

Comments: Soft and easy to spin. The grist was even but thicker than intended. It is not clear why. The fiber is not coarse. I spun it on a spindle and it spun thinner. It also spins thinner on a higher ratio on the spinning wheel.

Sample 9: Vreseis, Carded, Coyote Cotton: *Gossypium hirsutum*

Spinning Technique: Same as Sample 1.

| Staple Length: 1 inch |
| Sample of Commercial Coyote Sliver |
| 2-ply yarn zz/S |
| WPI: 24  TPI: 5.5 |
| Twist angle: 20°  Count: 6/2 |

Comments: Nice sliver, wonderful color, Easy to spin except in some compacted areas.
Sample 10: Cotton Clouds, Safford, AZ, Carded, Supima: *Gossypium barbadense*

Spinning Technique: Same as Sample 1.

<table>
<thead>
<tr>
<th>Staple Length: 1 ¼ inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample of Carded Supima Commercial Sliver</td>
</tr>
<tr>
<td>2-ply yarn zz/S</td>
</tr>
<tr>
<td>WPI: 25  TPI: 5  Twist Angle: 20°  Count: 6/2</td>
</tr>
</tbody>
</table>

Comments: This carded Supima has a nice sheen and a silky hand.

Sample 11: Cotton Clouds, Safford, AZ, Combed Supima: *Gossypium barbadense*

Spinning Technique: Same as Sample 1.

<table>
<thead>
<tr>
<th>Staple Length: 1 ½ inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample of Commercial Combed Supima Sliver</td>
</tr>
<tr>
<td>2-ply yarn zz/S</td>
</tr>
<tr>
<td>WPI: 25  TPI: 5.5  Twist angle: 20°  Count: 5.7/2</td>
</tr>
</tbody>
</table>

Comments: Soft, silky hand and a nice drape. I had difficulty maintaining consistent grist. The processing for combed cotton is steaming. This keeps the fibers straight for the machines to spin. This also makes the fiber more slippery and difficult to spin consistent grist.
Samples 1-5: Spinning with Ancient and Modern Cotton Preparations

The ancient techniques of bowing and beating are explored with these cottons, as well as the modern technique of carding cotton. The seed cottons were handpicked from cotton fields in Mesa and Tucson, Arizona. All of the cottons were finger ginned. A small portion of the finger ginned cotton is in each of the tables. Samples of the various preparations are also included. I spun the cottons on support spindles, a spinning wheel and a suspended spindle.

Spinning Cotton on a Suspended Spindle: Suspended spindles are suspended while spinning. There are many types. The Ahka people in Thailand, Burma, Laos and Yunnan Province in China, spin cotton on the Ahka spindle, a mid-whorl spindle.

To start, the spindle is held sideways with the bottom portion of the shaft in the spindle hand. The hook on the top of the shaft is put in the cotton with the fiber hand. The spindle hand then rolls the shaft clockwise until the hook catches the cotton. With the cotton hooked, the spindle hand pulls back on the cotton, twirling the shaft to add twist. When the yarn is approximately five inches long, the spinner rolls the bottom shaft on the thigh, and then drops the spindle. Now the spinner uses the spindle hand to draft and control the twist while the spindle spins. If the spindle is in the right hand, the shaft is rolled up the right thigh for clockwise spinning. If the spindle is in the left hand, the shaft is rolled down the left thigh for clockwise spinning. The cotton yarn is wound around the spindle above the whorl as needed. This is repeated many times until the spindle is full.
Table 6  **Sample 1: Acala Seed Cotton, grown in Mesa, Arizona**

Preparations noted next to samples. Comments next to yarns.

Spinning Technique: Spun and plied on the re-created support spindle except where noted with Ahka spindle and Lendrum spinning wheel.

| Acala Staple Length: 1 \(\frac{3}{8}\) inch  
Acala cotton used for all samples in Sample 1. |
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample of Finger Ginned Acala Cotton</td>
</tr>
</tbody>
</table>
| Single spun from finger ginned cotton without further preparations. WPI: 46  
Note: the singles were done separately, to show how the various cotton preparations affect the spinning. |
| 2-ply yarn. Spun from finger ginned cotton without further preparation. Lots of slubs  
WPI: 27  
TPI: 6  
Twist Angle: 20°  
Count: 10.8/2 |
| Sample of cotton beat with three-pronged sticks |
| Single spun from cotton beat with three-pronged sticks.  
WPI: 56 |
| 2-ply yarn spun with cotton beat with three-pronged sticks.  
Notable slubs and thin spots  
WPI: 25  
TPI: 5-6  
Twist Angle: 20°  
Count: 9/2 |
<table>
<thead>
<tr>
<th>Sample of cotton beat with a stick</th>
<th>Single spun from cotton beat with a single thick stick.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WPI: 46</td>
<td>2-ply yarn spun from cotton beat with a thick stick.</td>
</tr>
<tr>
<td></td>
<td>Less slubs and nepes</td>
</tr>
<tr>
<td>WPI: 24</td>
<td>TPI: 5-6</td>
</tr>
<tr>
<td>Twist Angle: 15°</td>
<td>Count 10.5/2</td>
</tr>
<tr>
<td>Sample of cotton carded with hand carders and rolled into a puni</td>
<td></td>
</tr>
<tr>
<td>Single spun from carded puni.</td>
<td></td>
</tr>
<tr>
<td>WPI: 58</td>
<td>2-ply yarn spun from carded punis.</td>
</tr>
<tr>
<td>Spun on spindle.</td>
<td>Plied on Lendrum wheel</td>
</tr>
<tr>
<td>Smoothest yarn.</td>
<td></td>
</tr>
<tr>
<td>WPI: 28</td>
<td>TPI: 7</td>
</tr>
<tr>
<td>Twist Angle: 15°</td>
<td>Count 13.5/2</td>
</tr>
<tr>
<td>Sample of bowed cotton</td>
<td></td>
</tr>
<tr>
<td>Single spun from bowed cotton</td>
<td></td>
</tr>
<tr>
<td>WPI: 46</td>
<td></td>
</tr>
</tbody>
</table>
2-ply yarn spun from bowed cotton.  
Fiber opened up with bowing, trash fell out,  
spun easily. Spun from bowed cotton.  

WPI 37  
TPI: 5.5  
Twist Angle: $20^\circ$  
Count: 12/2

Small Portion of a Sample of a Thick Pun

Single spun from bowed cotton. Then  
rolled into a thick puni.  
WPI: 72  
This was a surprise for me. The thick puni  
drafted easily with very few slubs

2-ply yarn spun from bowed cotton. Then  
rolled into a thick puni.  
WPI: 40  
TPI: Ave. 6.5  
Twist Angle: $20^\circ$  
Count: 18/2

Single: Thick puni spun with Ahka spindle.  
The thick puni did not draft as easily on the  
Ahka spindle. My preference is spinning  
with the thick puni versus spinning directly  
from the bowed cotton. WPI: 50

2-ply yarn spun with bowed cotton. Then  
rolled into thick puni.  
Spun with Ahka spindle, plied with support  
spindle  

WPI: 28  
TPI: Ave. 6-7  
Twist Angle: $20^\circ$  
Count: 10.8/2

Comments: I did all of the preparations and spinning with the Acala first. This helped me  
decide which ones worked best. The cotton that was beat with a stick and the bowed  
cotton with the thick puni made a nicer, more consistent yarn. For Sample 1, I included  
all of the various preparations. For the Samples 2 -5, I used only four preparations—  
finger ginning, beating with a stick, bowing then rolling into a thick puni and carding.
Sample 2: Pima Seed Cotton, grown in Mesa, Arizona

Preparations noted next to samples.

Spinning Technique: Spun and plied on the Prehistoric Colombia support spindle. Carded puni – spun and plied on Lendrum spinning wheel.

<table>
<thead>
<tr>
<th>Sample Description</th>
<th>WPI</th>
<th>TPI: Ave.</th>
<th>Twist Angle</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-ply yarn, finger ginned cotton without further preparation.</td>
<td>29</td>
<td>5-6</td>
<td>15°</td>
<td>10.8/2</td>
</tr>
<tr>
<td>Note: Satin feel, some areas less silky and shorter – all from same field.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-ply yarn spun from cotton beat with a stick.</td>
<td>32</td>
<td>5</td>
<td>15°</td>
<td>10.8/2</td>
</tr>
<tr>
<td>2-ply yarn spun from bowed cotton.</td>
<td>34</td>
<td>5-6</td>
<td>15°</td>
<td>12/2</td>
</tr>
<tr>
<td>2-ply yarn spun from carded punis. Spun on a wheel.</td>
<td>31</td>
<td>6</td>
<td>20°</td>
<td>9.8/2</td>
</tr>
</tbody>
</table>

Staple length Pima cotton 1½ inch
Pima cotton used for all samples in Sample 2.

Sample of finger ginned Pima cotton

WPI: 29      TPI: Ave. 5-6  Twist Angle: 15°   Count: 10.8/2

WPI: 32      TPI: Ave. 5    Twist Angle: 15°   Count: 10.8/2

WPI: 34      TPI: Ave. 5-6  Twist Angle: 15°   Count: 12/2

WPI: 31      TPI: Ave. 6    Twist Angle: 20°   Count: 9.8/2
Sample 3: Zarah’s Brown Cotton, grown in Picture Rocks, Arizona

Preparations noted next to samples.
Spinning Technique: Spun and plied on the re-created support spindle.
Carded puni – spun and plied on Lendrum spinning wheel.

<table>
<thead>
<tr>
<th>Staple length Zarah’s brown cotton ¾ inch</th>
<th>Sample of finger ginned Zarah’s brown cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zarah’s brown cotton used for all samples in Sample 3.</td>
<td>2-ply yarn spun from finger ginned cotton without further preparation. Difficult to maintain consistent grist possibly due to short staple.</td>
</tr>
<tr>
<td>2-ply yarn spun from cotton beat with a stick.</td>
<td>WPI: 24  TPI: Ave. 5  Twist Angle: 15°  Count: 6/2</td>
</tr>
<tr>
<td>2-ply yarn spun from bowed cotton.</td>
<td>WPI: 24  TPI: Ave. 6  Twist Angle: 20°  Count: 8/2</td>
</tr>
<tr>
<td>2-ply yarn spun from carded punis. Spun on a wheel.</td>
<td>WPI: 23  TPI: Ave. 5  Twist Angle: 15°  Count: 9/2</td>
</tr>
</tbody>
</table>
**Sample 4: Zarah’s Green Cotton, grown in Picture Rocks, Arizona**

Preparations noted next to samples.

Spinning Technique: Spun and plied on the re-created support spindle.

Carded puni – spun and plied on Lendrum spinning wheel.

<table>
<thead>
<tr>
<th>Sample of finger ginned Zarah’s green cotton. Note: Some color variation – white and brown with green all in same boll</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-ply yarn spun from finger ginned cotton without further preparation.</td>
</tr>
<tr>
<td><strong>WPI:</strong> 31  <strong>TPI:</strong> Ave. 5-6  <strong>Twist Angle:</strong> $15^\circ$  <strong>Count:</strong> 12/2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2-ply yarn spun with cotton beat with a stick.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WPI:</strong> 26  <strong>TPI:</strong> Ave. 6-7  <strong>Twist Angle:</strong> $15^\circ$  <strong>Count:</strong> 10.8/2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2-ply yarn spun with bowed cotton.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WPI:</strong> 32  <strong>TPI:</strong> Ave. 7  <strong>Twist Angle:</strong> $20^\circ$  <strong>Count:</strong> 12/2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2-ply yarn spun from carded punis. Spun on a wheel.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WPI:</strong> 33  <strong>TPI:</strong> Ave. 6  <strong>Twist Angle:</strong> $15^\circ$  <strong>Count:</strong> 10.8/2</td>
</tr>
</tbody>
</table>
Sample 5: Sacaton Aboriginal, grown in Abiquiu, New Mexico

Preparations noted next to samples.

Spinning Technique: Spun and plied on the prehistoric Colombia support spindle.
Carded puni – spun and plied on Lendrum spinning wheel.

Staple length Sacaton Aboriginal: ¾ inch
Sacaton Aboriginal cotton used for all samples in Sample 5

Sample of Sacaton Aboriginal cotton

2-ply yarn spun with finger ginned cotton without further preparation.

WPI: 32  TPI: Ave. 6
Twist Angle: 20°  Count: 13.5/2

2-ply yarn spun with cotton beat between a blanket. The seeds were picked out.
This preparation was not as consistent or easy to spin as beating with a stick.

WPI: 28  TPI: Ave. 5
Twist Angle: 15°  Count: 10.8/2

2-ply yarn spun from bowed cotton,

WPI: 36  TPI: Ave. 7
Twist Angle: 20°  Count: 13.5/2

2-ply yarn spun from carded punis.
Spun on a wheel.

WPI: 31  TPI: Ave. 7
Twist Angle: 25°  Count: 12/2
TECHNIQUES FOR FINISHING YARNS

Plying Yarns Together: A single is a yarn that is not plied. It is acceptable for use in weaving for warp and weft. However, a single has active twist that can cause knits to bias and sewing thread impossible to control unless steamed. Plying is a technique used to twist two or more yarns together. Plying makes yarns stronger; it increases the size (grist) of the yarn for a thicker thread; and it balances the yarn so it does not kink and tangle.

There are several options of plying with spindles. The ply ball is one I like the best. A good ply ball is small and firmly felted. For a 2-ply yarn, at least two spindles (or two bobbins or some other holders) with singles are needed. The holders are placed in a box where they can unroll easily. Pull a single yarn from each spindle or holder and hold the two together tightly. Then wrap these two yarns together around the ply ball, keeping the tension taut on the yarns. Once all of the yarn is wound onto the ball, hold the ball in the fiber hand and attach the end to the spindle. Pull out a length of yarn from the ball, pinch the yarns together at the ply ball, then spin the spindle counterclockwise (if the singles were spun clockwise) to ply the yarns together. Wrap the plied yarn onto the spindle and repeat the process until all the yarn is plied and on the spindle. Additional information and pictures for ply balls are in the Appendix.

Plying on the spinning wheel requires two or more bobbins with handspun yarn. The bobbins are held on a holder that allows the bobbins to move but with some slight resistance. The back hand should be held still. Moving the back hand forward and back will cause the yarns to tangle. The yarns are attached to the leader on the wheel and spun counterclockwise (if spun clockwise). Some spinners keep a finger between the strands.
so that they ply evenly without one wrapping around the other. To keep the twist consistent, count the number of treadles with each length of yarn.

**Finishing Yarns:** For knitting, crochet, embroidery or many other uses for handspun cotton, it is best to finish the yarn. First, wind the yarn into a skein and tie the skein in three to four places with figure eight ties. Soak the skein in hot tap water, with a small amount of mild soap that has a surfactant, for a minimum of 30 minutes. Then rinse the yarn in warm water and squeeze the yarn without wringing. Roll the yarn in a towel to hasten drying. Finally, I put my hands inside the skein and snap eight to ten times around the skein. Then I lay it flat to dry. Once dry, it is ready for any technique.

For weavers, it is not necessary to finish the yarn. The finishing is done after the fabric is woven. The woven fabric is soaked in warm water. This is followed by a spin in the washing machine to remove the rest of the water. Then the fabric is laid out to dry. Woven cotton fabric is usually improved by ironing.

**RE-CREATING HANDSPUN YARN USED IN ARCHAEOLOGICAL ARTIFACTS**

There are several highly respected museums in Tucson, Arizona with large collections of ancient cotton artifacts dated from 700 – 1400 CE. I was privileged to gain access to these collections to photograph (without flash) and handle with gloves, the prehistoric fragments of cloth, handspun yarns, raw cotton and prehistoric cotton seeds. My purpose was to learn how the cotton was prepared, spun and used. I found a new appreciation for the skill of these ancient people. In keeping with the type of cotton used in the prehistoric Southwest, all of the samples in this section are done with *Gossypium hirsutum* v. *punctatum* subv *Sacaton* (Sacaton Aboriginal). The staple length for this cotton is \( \frac{5}{8} \) inch. The cotton was finger ginned, beaten with a stick and formed into a lap
for each of the samples. This was done for consistency and in keeping with the most common of the New World preparations for spinning based on the Oaxaca, Mexico and Peruvian spinners of today.

A good place to start for the first sample is with the yarn. This is a 3-ply yarn, spun Z and plied S. I measured the diameter of this yarn at 1 ½ to 2 mm with a ruler, trying not to disturb this ancient artifact. This is approximately 17 wraps per inch. The yarn has some variation in grist. The inconsistency may be due to weathering, the spinner or both.

Table 7

Sample 1: Re-creating the Prehistoric 3-ply Yarn

Preparation: Finger ginned, beaten with a thick stick forming it into a lap.
Spinning Technique: Spun and plied with the prehistoric Colombia support spindle

<table>
<thead>
<tr>
<th>WPI</th>
<th>TPI</th>
<th>Count</th>
<th>Twist angle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>5</td>
<td>7.7/3</td>
<td>30°</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>5</td>
<td>30°</td>
<td></td>
</tr>
</tbody>
</table>

Comments: Plied yarns were commonly used to apply a twined edge to woven cloth and rugs. The plies can be 2-ply up to 5-ply.
Braiding is common around the world and predates the loom (Kent, 1957, p.600). Braids are used for belts, hair ties, rope, bags, tassels and more. This braid sample is believed to be part of a belt. It is made with a loosely plied 2-ply yarn. The measurements of the braid fragment are 2 ½ x 2 inches (slightly magnified here).

**Sample 2: Re-creating a 2-ply Yarn for a Prehistoric Braid**

- Preparation and spinning same as Sample 1
- Single WPI: 36
- zz/S, 2-ply yarn.
  - WPI: 24  TPI: 3.5  Twist angle: 15°
  - Count: 7.7/2
- Flat Braid – 2 over 2
  - Comments: In the braid, each wrap has 2 threads making the yarn loosely plied. I made the cotton yarn with a same soft twist and did this small sample to see if this almost un-plied look appears in the braid. It does in most areas.
Among the ancient artifacts I examined were many loom-woven plain weave pieces. Figure 34 shows a plain-woven piece with a warp at 5 EPI and a weft at 10 PPI. The warp yarn measures 1 mm and the weft 2 mm, as compressed in the weave. This is a weft-faced fabric. The actual measurement of the piece is 7 x 3 ½ inches.

Figure 34  
Woven Weft Faced Cloth

Sample 3: Re-creating Yarn for a Prehistoric Plain Weave Cloth

Preparation and Spinning Technique: Same as Sample 1

<table>
<thead>
<tr>
<th></th>
<th>Weft singles at approximately 2 mm</th>
<th>WPI: 21</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warp singles at approximately 1mm</td>
<td>WPI: 30</td>
</tr>
</tbody>
</table>

Comments: This cloth was done in singles, so there are no samples of plied yarns.
Weft-wrap openwork is one of the most beautiful of the ancient techniques. This technique did not survive to historic times. Kent (1957, p. 501-506) describes the technique and provides excellent charts for those who wish to re-create one of these lovely designs. The original piece measures $15\frac{3}{8} \times 12\frac{1}{2}$ inches. The warp is 25 EPI; the weft is 20 PPI. It has suffered damage, but I magnified a small portion to show the lacy openwork.

Sample 4: Re-creating Yarn for a Prehistoric Weft-Wrap Openwork and Woven Cloth

<table>
<thead>
<tr>
<th>Preparation &amp; Spinning Technique:</th>
<th>Same as Sample 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weft and warp single</td>
<td></td>
</tr>
<tr>
<td>WPI: 37</td>
<td></td>
</tr>
<tr>
<td>3-ply Yarn for additional weft wrapping; $zzz/S$</td>
<td></td>
</tr>
<tr>
<td>WPI: 31 TPI: 5.3</td>
<td></td>
</tr>
<tr>
<td>Twist angle: $20^0$ Count: 12/3</td>
<td></td>
</tr>
<tr>
<td>Comments: The holes are made by taking a weft around the warps to open the holes while on the loom. Likely a needle is used for the more complex patterns.</td>
<td></td>
</tr>
</tbody>
</table>

Figure 35

Weft-Wrap Openwork

2151 Arizona State Museum Dated 900-1100 CE
Cloth belts were used in the prehistoric world. This one is unusual because of the warp floats on each side of the belt that add decoration. The weft selvedge had a thick blue single yarn twined to protect the edging. That can be seen in at the bottom of the photo. The belt is 40 ½ x 3 ½ inches with one end frayed. Only a portion of the belt is seen in the photo to highlight the decorative warp floats and the at the selvedge cord.

Sample 5: Re-creating a Yarn for a Prehistoric Warp Float Decorated Belt

Preparation and Spinning Technique: Same as Sample 1

Warp, warp floats and weft single:
WPI 36

Comments: The weft PPI is spaced wider than the warp EPI. It is difficult to tell if there is a significant difference between the grist of the weft, warp and floats. I chose to use the same yarn for all of them. The EPI (ends per inch) of the warp is 20.
Another wonderful piece is this black and white Weft Float Pattern (Figure 37) somewhat similar to twill. The black threads are dyed with a vegetal dye (Kent, 1954). These fabrics were not common in archaeological collections (Kent, 1957, p. 565). The fragment measures about 7 x 3 inches with a 32 EPI and 25 PPI. The only remaining border is twined with a 3-ply yarn. These patterns seem most often used for bags.

Figure 37
Weft Float Pattern Weave

Sample 6: Re-creating a Yarn for a Prehistoric Weft Float Pattern Weave

Preparation & Spinning Technique: Same as Sample 1

| Warp and weft single: WPI: 44 |
| Comments: The yarns in this weave are closely set. The closely packed threads seem to make a thick fabric. I created a thin yarn for the close set that would be functional for a bag. |
The final artifact is a sample of the ancient cotton. These are very small compared to the cotton we have today. There is only the outer portion of the ancient cotton boll and some ancient cotton seeds compared with a modern cotton boll - an Acala cotton boll from 2014.

CONCLUSIONS

Cottons are different, not only from year to year, field to field or bale to bale but from plant to plant. On the same cotton plant there can be flowers, squares, pods and bolls. The cotton fiber from one plant can be coarser and shorter than the cotton fiber on another plant or even on the same plant. It may be due to the cotton opening earlier or later in the fields, temperature changes, or a difference in the soil. There could be many
other reasons. This explains the variations that spinners find in spinning cotton. It is well known that sheep's wool varies with the age and health of the animal despite the expectation of a standard wool in a specific breed. Cotton has the potential for even more variations.

Preparation matters; it is a fact. No matter what the preparation is, the hand spun yarn is always smoother with some preparation rather than none. The less the preparation the more slubs, neps and thin spots occurred in my spinning. I noticed if the yarn was spun thin, these irregularities were less obvious. I compared the less prepared yarns to the yarns with better preparations; the yarns with the better preparation were smoother and more even than the thin, less prepared yarns.

My personal favorite preparation was the ancient technique of beating with a stick. For me, this was the easiest to spin from and made a smoother yarn. My next favorite was bowing, and then rolling the cotton on a dowel into a thick, compact puni. The thick puni drafted nicely despite the compaction in the puni. Hand carding was comparable to beating and bowing for smoother, easier spinning.

Yarns spun by the ancients were a surprise. I thought all of their yarns would be singles, as singles are faster to make then plied yarns. Obviously, the ancients had to make all of their clothing. Today's weavers make cloth for art, relaxation and to sell, generally not out of necessity. Plied yarns require more time. Perhaps, the added durability and decoration was the purpose for the 2-ply, 3-ply, 4-ply and 5-ply yarns I saw in the collections. Many of the plied yarns were used for twining the edges of cloth and some were made for decorations in the cloth, for braiding and for ties.
Kent (1957, pp. 671-691) has a chart of PPI and EPI for the ancient cotton singles in plain weave that range from 12 to 54. The most common PPI and EPI were in the 20’s. This does not correlate to the grist as the PPI or EPI can be spread out when weaving but this does provide a generalization of how thin most of the singles are. The only thick yarn I examined was the weft faced fabric (Figure 34) where the weft yarn was thicker than the warp yarn. The thicker yarn measured at 2 mm on a ruler. If the wraps per inch were even, this would be approximately 12 wraps per inch. From my study, the grist of the ancient cotton yarns is similar to the grist of the cotton yarns that spinners spin today.

The Sacaton Aboriginal cotton available from Native Seeds/SEARCH in Tucson is as close as we can get to the cotton grown in the prehistoric American Southwest. The staple length of this cotton is very short, varying from $\frac{1}{4}$ to $\frac{5}{8}$ inches in length. The commercial cotton growers of today produce long stapled cottons from 1 inch to 1 3/4 inch. However, the ancient cotton artifacts made with short stapled cotton have endured thorough the ages.

All singles are weaker than any plied yarn. Less twist in a single yields a softer yarn usually used for weft for a soft, next to the skin garment. More twist in a single makes a stronger yarn for warp and weft for a bag or outer garment. The increased twist makes the singles yarn snarl and kink. This can be remedied by keeping tension on the warp. Another option is dressing the warp by applying a liquid on the warp while stretched. Today’s dressing for warps vary from cornstarch to gelatin to flaxseed. I could not find any information on this in the prehistoric era but it is possible that dressing for warps was used. There are a number of plants in the Sonoran desert that could make a
similar dressing for warp such as the Prickly Pear cactus that has a mucilaginous core in
the pads that is similar to gelatin.

Now hand spinners have a lot more options with the luxury of all kinds of well-
made spindles, wheels and looms. The ancient people had fewer sophisticated tools but
they were expert with what they had. Their skill at their looms was inspiring. Clearly, the
ancients wove art. The intricate weaves such as Weft-wrap Openwork and Weft Float
patterns are amazing. It was a delight and honor to see their work.

Commercial processing changes cotton fiber. This is similar to working with
combed or carded raw wool fleece versus machine prepared top. Prepared cotton sliver is
different than raw cotton. The difference is due to the processing and the resulting
uniformity of the sliver. Raw cotton feels different. Raw cotton processed by hand has a
lively, almost springy feel. That does not mean that I will not use processed sliver but it is
very nice to work with raw cotton; preparing, spinning and making cloth.
Appendix: Definitions

Angle of Twist:

The angle of twist is the degree the fibers in a yarn slant after being spun. This is measured using a protractor starting at 0 where there is no twist. The angle is most easily measured in a plied yarn. The yarn is held maintaining a 0 axis and moved along the protractor until the angle in the yarn matches one of the angles of the protractor. The degree of that angle is then read as the angle of twist.

Batt: formed by carding – either by hand or by machine.

Bradford Count: is the number of skeins of a given length that can be spun from one pound of fiber (Olds College, 2014). The calculation for cotton is: yards of yarn/weight of yarn in ounces (or grams) x 16 ounces (or 454 gms) x number of plies/840.

Example: 10 yds /2 gm x 454 x 2-plies/840 = 8 skeins of cotton yarn. The count would be 8/2. To determine the yards per pound, multiply the count by the fixed weight (840) and divide by the number of plies. Using the example above: 8 x 840 = 6720/2 = 3360 yards in one pound.
**Cotton Bolls:** the pod of fruit containing the cotton. When mature the pod bursts open, displaying the locks of cotton that soon dry and can be picked or harvested.

**Cultivation:** the process of changing plants by planting, changing the soil, caring for the plants, or any manner that will alter the plant.

**Cultivars:** plants that have produced by selective breeding or genetic manipulation.

Modern science can use breeding and genetics to increase plant’s resistance to pests and diseases, increase crop production such as making cotton fibers longer and alter the plants to need less water.

**Ends per Inch (EPI):** In weaving, the ends per inch are the number of threads in the warp. The EPI is spread to allow for the threads from the weft. For a plain weave cloth the EPI is generally half of the wraps per inch. Example: If the wraps per inch were 40 threads, the EPI would be 20.

**Fuzzy Seeds:** sometimes called sticky seeds, these cotton seeds have fibers that stick to the seed. Fuzzy cotton seeds are *Gossypium Hirsutum*.

**Lap or Lapp:** a thin, wide flat formation of cotton fibers used in mills. Hand spinners are using these same terms for similar preparations for spinning. Such as the ancient technique of beating cotton into a flat, compact rectangle - a lap - that can be placed on a distaff, or rolled into a soft ball for spinning.

**Lint:** cotton when the seeds have been removed

**Linters:** the tiny cotton fibers left on the seeds after the cotton has been commercially ginned.
**Micronaire**: a measure of the air permeability of compressed cotton fibers as an indication of fiber fineness and maturity. The micronaire is very important in determining how easily cotton fiber can be processed.

**Naked Seeds**: also known as black seeds, these cotton seeds can fall out of cotton or be easily removed. This type of seed is usually seen in *Gossypium barbadense* cotton although occasionally other cottons will produce similar seeds such as *Gossypium Hirsutum v. punctatum subv Sacaton*. With many cultivars of *G. barbadense* some have produced seeds that are not as easily removed.

**Pangaea**: a supercontinent on earth, about 300 million years ago, made from smaller continents thought to drift together or impact as a result of tectonic plates. Pangaea began breaking up about 175 million years ago. Supercontinents are believed to have formed and broke up in a cycles throughout Earth's history.

**Picks per Inch (PPI)**: PPI are the threads that go across the warp threads to create the woven cloth.

**Ply Ball**: a great technique for keeping two singles under tension while plying them together on a spindle. A small firm felted ball works well as it is comfortable to hold and stiff enough to keep the singles wrapped around the ball. The key to make this work is to keep tension on the yarns when wrapping around the ball and when plying onto the spindle.

Hold two singles tightly while wrapping them firmly around the ball. The ball will hold a large amount of yarn, limited only by how
much the hand can hold. To ply, tie the two threads from the ply ball to the spindle with a slip knot. Pull a length of yarn from the ball keeping tension on the threads. Pinch the threads at the ply ball and spin the spindle counterclockwise (if spun clockwise) until there is sufficient twist in the ply. Then keep pinching the threads while winding the yarn onto the spindle. Then repeat: Pull out another length of yarn, maintaining tension, pinching the threads at the ply ball, spinning the length counterclockwise and winding onto the spindle.

**Puni:** preparation for hand spinning cotton originated in India. Cotton is carded, then rolled off the hand card with a stick, allowing the cotton to wrap around the stick.

**Seed Cotton:** cotton that still has seeds. This is a term used by the cotton farmers and those who gin cotton.

**Squares:** the flower bud on a cotton plant. Squares are two leaves different from the plant leaves. Squares appear before the flowers. The flower grows inside the square. The square opens as the flower grows. When the flower dies, the cotton boll develops inside the squares and out grows the squares.

**Sliver:** machine carded cotton in a continuous rope-like bundle with no twist. Sliver is the term used by most cotton researchers and cotton mills. Roving may be part of the process but the term roving is not used for cotton. In wool mills, sliver refers to the first process in carding before it becomes roving that does have twist.

**TPI:** Twist per inch (tpi) can be easily measured in a plied yarn. Each twist along the side of the yarn leaves a little bump. The bumps are counted over an inch of yarn. The tpi of
the plied yarn is then calculated by dividing the number of bumps by the number of plies. The tpi in a single can also be measured by counting the bumps. The number of bumps in a single over an inch equals the tpi. Counting this in a single can be difficult especially in a fine yarn but it is possible with a magnifying glass.

**Warp:** In this paper, warp is a reference to weaving. The warp is the threads that are wound around the loom and held taut during weaving. The loom can be as simple as two sticks that the warp wraps around and tensions before weaving.

**Weft:** The weft are the threads that go across the warp in an over and under fashion to create plain weave and complex designs.

**WPI:** Wraps per inch is measured by wrapping a yarn around a ruler, dowel rod, flat wood, plastic or cardboard with the inches marked or carved out of the wrapping tool. The yarn is wrapped around the device over at least an inch without stretching the yarn. Each wrap is next to the previous one without leaving spaces or overlapping. Once the inch space is filled the number of wraps are counted to determine the wpi. If the yarn has variable areas in grist, the wrapping should be repeated several times and the average taken as the wpi.
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