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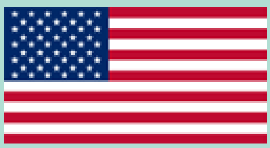

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Content

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News

Members updated on progress in cotton trade and development assistance at WTO cotton meetings

The Cotton-4 (Benin, Burkina Faso, Chad and Mali) and other WTO members held discussions on trade-related aspects of cotton and on cotton development assistance at WTO cotton meetings on 27-28 May. Members also discussed the state of play for a draft General Council Declaration on Support for Cotton By-Products Development in Least Developed Countries (LDCs), and the possible next steps for the Joint Initiative on Cotton By-Products through the secretariats of the WTO, International Trade Centre (ITC) and the UN Conference on Trade and Development (UNCTAD).

Members also endorsed the Cotton-4's suggestions to include a new standing item on the agenda relating to "COVID-19 and Cotton" in the bi-annual Dedicated Discussions on cotton and to invite the WTO Secretariat to conduct a study to assess the impact of COVID-19 on the cotton sector in LDCs.

Celebrations of World Cotton Day 2021

The WTO Secretariat reported on preparations for the 2nd anniversary of World Cotton Day, indicating that this year's celebrations are expected to be in virtual format, as was the case in 2020. The WTO Secretariat is preparing a call for participation that will be circulated among members, partner organizations, civil society and academia.

The aim of World Cotton Day is to increase awareness about the benefits of cotton and its positive impact on millions of people worldwide. The International Cotton Advisory Committee (ICAC) suggested that the theme for this year's event be "Cotton for good", with the aim of ensuring more engagement from brands and retailers.

The launch of World Cotton Day was hosted by the WTO on 7 October 2019 in collaboration with the UN Food and Agriculture Organization (FAO), UNCTAD, ITC and ICAC.

Cotton development discussions

During the 35th Round of Consultations of the Director-General's Consultative Framework Mechanism on Cotton, ICAC highlighted recent developments in the cotton market and cotton technologies for Africa. According to ICAC, cotton production and consumption are expected to increase in 2021/22, with production in West Africa expected to reach 1.5 million tonnes, representing 38% growth. ICAC also noted that Africa has lagged behind in adopting new technologies. It outlined six technologies that can make a big difference if adopted, especially for small cotton farmers in LDCs.

The Cotton-4 countries stressed the significant impact the COVID-19 pandemic is continuing to have on the cotton industry. The group called on members to show greater transparency in reforms to the cotton sector, including market access commitments. Additionally, the group called for the removal of restrictive commercial measures that could adversely affect cotton trade, which is an important source of income for a number of LDCs.

The Cotton-4 asked technical and financial development partners to help them with the regional "Cotton Roadmap Project", which seeks to respond to issues in the cotton sector linked to productivity, marketing, value-addition and promote the cotton sector by improving local processing capacity and developing cotton-to-textile value chains at the regional level. They also requested support with regards to transfer of technology for the development of cotton value-added industries, including by-products, and international trade. Developing members expressed their willingness to continue to be reliable partners in South-South cooperation projects. The Cotton-4 also encouraged members to pursue efforts to produce significant outcomes on cotton by the 12th Ministerial Conference (MC12), which begins on 30 November, and suggested a roundtable on funding of cotton projects as a side event during the meeting.

The WTO Secretariat highlighted the main updates in the latest revised Evolving Table on Cotton Development Assistance (WT/CFMC/6/Rev.30). Despite a decrease in the committed amounts for cotton-specific programmes, the number of active cotton projects recorded in the latest version of the Evolving Table has increased from 26 to 27. Australia, Brazil, Canada, Germany, Japan and partner organizations FAO, UNCTAD and the United Nations Industrial Development Organization provided inputs to the revision of the Evolving Table.

Representatives from the Intellectual Property Division of the WTO Secretariat gave an overview on technology transfer to LDC members, focusing on technology transfer in the field of agriculture technology. The Secretariat noted that it organized a series of annual workshops that provided practical focused discussions on technology transfer in the agriculture sector to assist LDCs in better understanding priorities for technological development.

All presentations made in the session are available here.

New WTO cotton web page

The WTO Agriculture Division gave a presentation on the new web page for the Joint Initiative on Cotton By-Products. The web page groups together all information relevant to the joint initiative, including how it came to be, its objectives and results.

The page also includes WTO member presentations on their experiences with cotton by-products development, and useful links that give access to articles and videos produced under the initiative as well as to the WTO-ITC's Cotton Portal, an online tool to access data on cotton.

The World Economic Forum published a video on the potential for cotton by-products development in Africa, which was also presented at the meeting.

Draft General Council Declaration on Support for Cotton By-Products Development in LDCs

The Cotton-4 updated members on the draft General Council Declaration on Support for Cotton By-Products Development in LDCs as contained in document WT/GC/W/808. The group underlined the importance of increasing productivity, processing and development of cotton by-products in LDCs. The Cotton-4 also noted its readiness to improve the text of the Declaration. Together with the representative of the LDC Group, it appealed to other WTO members and development partners to cooperate on the adoption and effective implementation of the plan of action contained in the draft Declaration.

Progress in WTO-UNCTAD-ITC initiative on cotton by-products

Members gave an update on Phase I of the WTO-UNCTAD-ITC joint initiative on cotton by-products. The Cotton-4 countries and Mozambique shared the results of individual feasibility assessment studies. The WTO Secretariat, ITC and UNCTAD updated members on Phase I progress while UNCTAD shared information on ongoing feasibility assessment work in Malawi and Togo, a project funded by the Enhanced Integrated Framework.

Members concluded that the focus should be on targeting the specific needs of countries while considering the sub-regional potential for integration resulting from attracting investment and technologies for cotton by-products development in Africa. The secretariats of ITC and UNCTAD also updated members on a Phase II proposal circulated in document WT/CFMC/W/89. The second phase will be tailored to supporting national action plans and projects for selected cotton by-products.

COVID-19 and cotton

At the 15th Dedicated Discussion of relevant trade-related developments held on 28 May, the Cotton-4 stressed the devastating impact the COVID-19 pandemic is continuing to have on the cotton industry. The group called on the removal of restrictive commercial measures that could adversely affect cotton, which is one of the primary sources of income for LDCs.

The Cotton-4 proposed to include COVID-19 and cotton as a standing item on the agenda, starting with the next meeting in November, to continue monitoring the effects of the pandemic. The group also suggested the WTO Secretariat prepares an information note that will look at the impact of COVID-19 on the cotton sector in the Cotton-4 countries and other LDCs. Both proposals were endorsed by members.

Trade-related discussions on cotton

Ambassador Gloria Abraham Peralta of Costa Rica noted that the facilitators' led process initiated in October 2020 had ended and referred members to the last report of the facilitators (Burkina Faso and Brazil) during the Committee on Agriculture in Special Session. In view of members' apparent readiness to explore ways to improve cotton-related transparency, she urged members to intensify their efforts in the coming weeks.

The Cotton-4 renewed its call for an outcome on cotton at the 12th Ministerial Conference and for increased transparency on members' cotton-related policies. The African Group supported this call, while several other members expressed their readiness to explore ways to enhance cotton-related transparency.

The WTO Secretariat presented a revised "background paper" (TN/AG/GEN/34/Rev.14 and two addenda) compiling up-to-date information on cotton policies in the areas of domestic support, market access and export competition. The Secretariat in its presentation announced an upcoming IT project to enable online submission of replies to the bi-annual cotton questionnaire and search and download reports of cotton-related data. Members welcomed this initiative. All presentations made in the session are available here.

Cotton Portal and the new user survey

ITC updated the participants on the Cotton Portal, which was launched during the 2017 Buenos Aires Ministerial Conference. The online tool provides a single-entry point for all the cotton-specific information on market access, trade statistics, country-specific business contacts, development-assistance information, and up-to-date ICAC statistics. Several improvements were introduced to the digital tool since its launch. With the objective of continuing to enhance it, the WTO Secretariat and ITC have developed an online survey to assess the needs and expectations of potential users.

The survey can be found here: English https://bit.ly/3oNlqBD and French https://bit.ly/3vnrFyi)

Source:
https://www.wto.org/english/news_e/news21_e/cott_28may21_e.htm

SUITABILITY OF US COTTON FOR VORTEX SPINNING

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About three-quarters of the U.S. cotton production is exported (Figure 1).

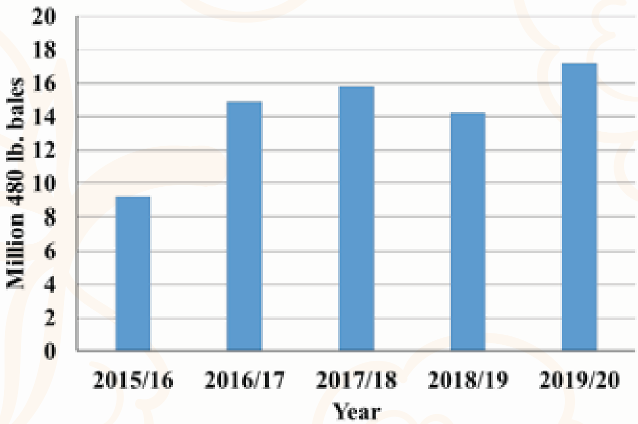

Figure 1. U.S. Cotton Exports (source Cotton Incorporated)

We need to produce cotton that fits the dominant market, i.e., Asia and ring-spun yarns. It means we need cotton with fibers that are long, uniform, mature, fine, strong, and with low contamination levels. It should be the strategy for the short-term but not for the long-term. Indeed, labor costs in Asia are increasing. It is forcing spinning mills to consider potential alternative spinning technologies such as air jet/vortex spinning. If cotton could be adapted to air-jet spinning, its throughput would make it competitive with rotor spinning (faster than rotor). It could produce yarns competitive with ring spun yarns in some market segments such as the 30Ne, the primary target market for U.S. cotton (the range of possible yarn counts is narrower than for ring spinning). However, The drawback is that it lowers mill throughput and increases waste, resulting in lower profits for the spinning mills. The Vortex or Air-jet spinning is emerging, as shown Table 1. This technology is an opportunity for U.S. cotton as ring spinning, because of labor cost, is not a viable option for the local transformation of the raw material. Only two spinning technologies can be economically implemented in the U.S., i.e., rotor and vortex spinning. Rotor is historically the dominant spinning method in the U.S. but Vortex is just beginning to appear in the textile mills (Table 1). In 1984, the U.S. textile manufacturing industry counted 300,000 rotor spinning positions and 14,330,000 ring spinning spindles. Ten years later, in 1994, we witnessed a dramatic increase in the number of rotor positions, i.e., 1,008,000 (+336%), and a rapid decline in the number of spindles, i.e., 6,261,000 (-56%). By 2004, the number of rotors were cut by nearly 45% and the number of spindles by 74%. For ring spinning, it represents a decrease of 88.8% compared to 1984. At its peak (1997), the U.S. textile manufacturing industry consumed 2,471,000 metric tons of cotton (about 10.8 million bales). At its lowest point, in 2011, the consumption of cotton in the U.S. shrunk to 718,490 metric tons (about 3.3 million bales). Since 2008, the consumption has oscillated between 3.3 and 3.8 million bales per year. The decreased consumption of cotton within the U.S. textile manufacturing industry led to an increased reliance on the international market for the sale of U.S. cotton. For example, for the

2018/19 crop year, about 14.8 million bales of cotton were exported, corresponding to 82.7% of the production.

Table 1. Installed spinning capacities (short-staple – in thousand) Source ITMF

		1984	1994	2004	2007	2010	2013	2016
Rotor	US	300	1,008	569	364	303	303	303
	China	100	550	1,160	2,037	2,260	2,720	2,850
Ring	US	14,330	6,261	1,602	1,043	670	670	870
	China	22,000	41,585	67,000	99,000	110,000	110,000	100,000
Air Jet	US	n/a	n/a	n/a	n/a	n/a	n/a	16
	China	n/a	n/a	n/a	n/a	n/a	n/a	157

Therefore, our ongoing project aims to determine the impact of fiber properties on vortex yarn quality.

In 2020, we purchased 20 high-quality upland cotton bales and established the protocols for incremental combing and vortex spinning. Fiber quality was analyzed by High Volume Instrument and Advanced Information System.

Each bale was processed in our short staple spinning laboratory and Ring and Vortex yarns were produced (both carded and combed) to produce 30Ne yarns.

Each bale was processed in our short staple spinning laboratory and Ring and Vortex yarns were produced (both carded and combed) to produce 30Ne yarns. The correlation coefficients among the main yarn quality parameters for carded ring spun yarns, and carded vortex yarns are relatively good on commercial bales (Table 2).

Nevertheless, it should be noted that several correlation coefficients are below 0.8, indicating that about one-third of the variability observed is not explained. It is the case for Elongation, CVm, and importantly for Thick places, where about 70% of the variance observed is not explained. It means that cottons that perform well in ring spinning may not perform well in vortex spinning. The main fiber properties of interest for vortex yarn tenacity are length distribution, HVI strength, and standard fineness (data not shown). Fiber length distribution appears to be an important contributor for work-to-break, number of thin places, and yarn hairiness. High correlations are also observed between yarn neps, number of thick places, and NCT Seed coat fragments.

Table 2. Main correlation coefficients among yarn quality parameters for carded ring spun yarns and Vortex carded yarns

N.B. red color indicates statistical significance – grey cells indicate correlation of major interest

Variable	Ten.	Work-to-break	Elong.	CVm	Thin places	Thick places	Neps 200%	Hairiness
Tenacity	0.950	0.623	0.157	-0.739	-0.627	-0.617	-0.240	-0.645
Work-to-break	0.581	0.863	0.851	-0.819	-0.850	-0.798	-0.335	-0.896
Elongation	0.159	0.595	0.789	-0.512	-0.592	-0.545	-0.231	-0.603
CVm	-0.629	-0.649	-0.477	0.795	0.673	0.774	0.727	0.774
Thin places	-0.748	-0.874	-0.725	0.906	0.891	0.868	0.534	0.965
Thick places	-0.346	-0.326	-0.212	0.533	0.370	0.543	0.764	0.479
Neps 200%	-0.379	-0.466	-0.405	0.653	0.508	0.687	0.838	0.606
Hairiness	-0.471	-0.801	-0.853	0.752	0.798	0.741	0.421	0.899

The results obtained demonstrate that vortex yarns are much weaker than ring-spun yarns made from the same fibers (Figure 2). Combing improves only marginally the tensile properties of the vortex yarns but improves yarn evenness drastically (Figure 3).

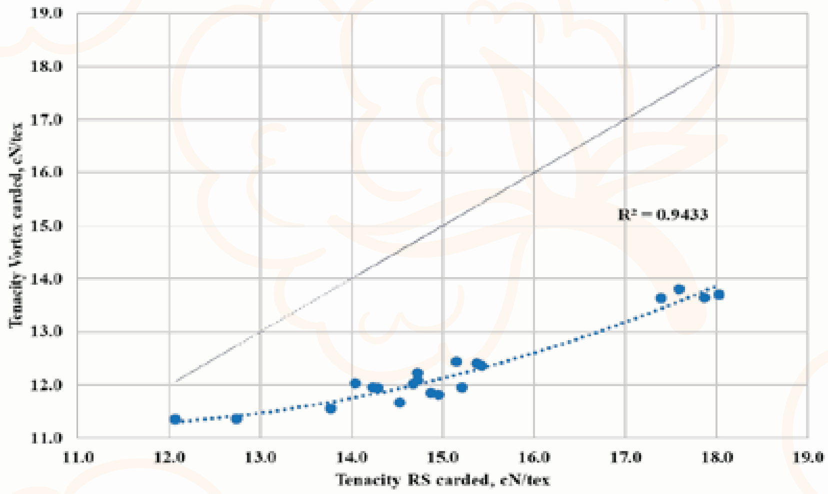

Figure 2. Ring-spun yarn tenacity vs. vortex yarn tenacity (carded)

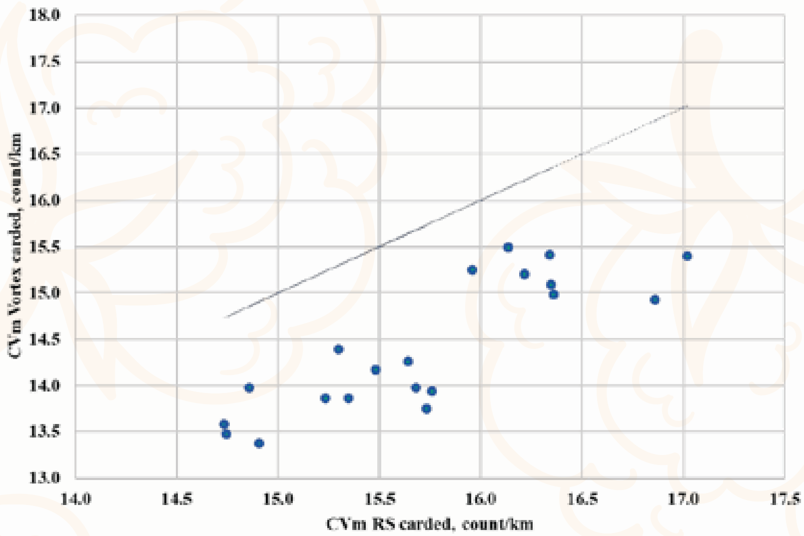

Figure 3. Ring-spun yarn CVm vs. vortex yarn CVm (combed)

In conclusion, it appears that fiber length distribution is a critical fiber attributes to obtain high-quality vortex yarns. Also, smaller fiber diameter translates automatically into a better bundle strength. These are preliminary results. This project is ongoing and we expect to release a complete report in 2022.

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Cellulose represents a renewable precursor for bioproducts development

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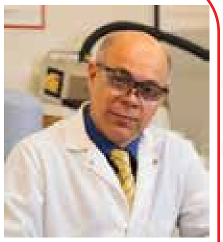


Cellulose is one of the most fascinating organic polymers on earth. It is considered the most abundant natural polymer with an estimated annual production of about 1.5 x 1012 tons (O'Sullivan, 1997). Moreover, it is a renewable natural resource, thus, making it a virtually inexhaustible source for bioproducts development. It has continuously been occupying a significant part of human culture through different shapes and forms since the beginning of human civilization. Wood pulp constitutes the most important source of raw material for cellulose. However, it can also be extracted from algae, bacteria, and plants including cotton (Klemm, Heublein, Fink, & Bohn, 2005). Often known as the "sugar of the plant cell wall', this natural polysaccharide is primarily composed of C, H, and O with the molecular formula (C6H10O5)n. Structurally, cellulose is the linear polymer of D-glucose units covalently linked together by β-1,4 glycosidic linkage. Every second anhydroglucose unit (AGU) is rotated 180˚ with respect to its neighbor forming a cellobiose unit, to accommodate the preferred bond angles. Each repeating unit in the cellulose structure contains three hydroxyl groups, one primary hydroxyl group at C6 position and two on C2 and C3 position. The presence of a large number of hydroxyl groups in its backbone allows chemical modification to develop varieties of cellulose derivatives and also to impart new functionalities. Moreover, this also presents the ground for an extensive hydrogen bond network in cellulose structure, which is mainly responsible for its properties such as crystallinity, chemical, and physical stability.

Cellulose has been an integral part of human culture since prehistoric times. Humans have used cellulose from different sources in different forms and shapes for a long time. It was reported that the use of cellulose sources such as hemp and cotton for the production of rope, cordage, and garments started around 4500 BC (Hon, 1994). Since then, the massive applications of cellulosic materials have gained momentum especially in textile/clothing industries and remains the most common use of cellulose. However, with the continuous development in technology and increasing understanding of the fundamental structure of cellulose, it has been processed to develop various products. Since the development of cellulosic fibers by dissolving plant materials in nitric acid (Hon, 1994), varieties of products were developed in different forms and shapes by processing cellulose for various applications.

Cellulose dissolution: Because of its biodegradability, low toxicity, biocompatibility, and renewability, cellulose is an attractive biopolymer for the production of novel materials for diverse applications, such as in pharmaceutical industry, automotive, aerospace, packaging, and medical fields (Klemm et al., 2005). However, because cellulose does not melt, it must be dissolved. Cellulose, because of its several hydroxyl groups, has good hydrogen-bond (H-bond) capability. However, it is difficult to dissolve in water and common solvents. The insolubility of cellulose has been attributed to its high crystallinity and more commonly to its inter- and intrachain H-bonds (Lindman, Karlstrom, & Stigsson, 2010). It has also been argued that its amphiphilic and hydrophobic interactions could also be important in determining its solubility behavior (Medronho & Lindman, 2014). The traditional cellulose dissolution processes (e.g., Viscose and Lyocell) involve relatively harsh conditions and the use of expensive and uncommon solvents (Heinze & Liebert, 2001).

Recent selected applications of cellulose: The use of eco-friendly bioplastics has become a viable solution to reduce the accumulation of petrochemical products in the biosphere and to decrease microplastic contamination.

Cellulose from low-quality cotton fibers, that lack textile applications, have been used to prepare bioplastics (Rumi, Liyanage, & Abidi, 2021). Cotton fibers were dissolved in N,N-dimethylacetamide/lithium chloride solvent system and converted to strong, transparent, and flexible films through casting, gelation, regeneration, plasticization, and hot pressing (Figure 1). Compared to raw cotton cellulose, regenerated and hot-pressed cellulose films showed amorphous structures and excellent tensile characteristics. The physical and mechanical properties of cellulose films, such as deformation recovery, flexibility, homogeneity, elongation, and surface roughness, were significantly improved by means of plasticization and hot pressing. Because glycerol plasticization increased the surface hydrophilicity of the films, plasma-induced surface grafting of oleic acids imparted hydrophobicity to cellulose films.

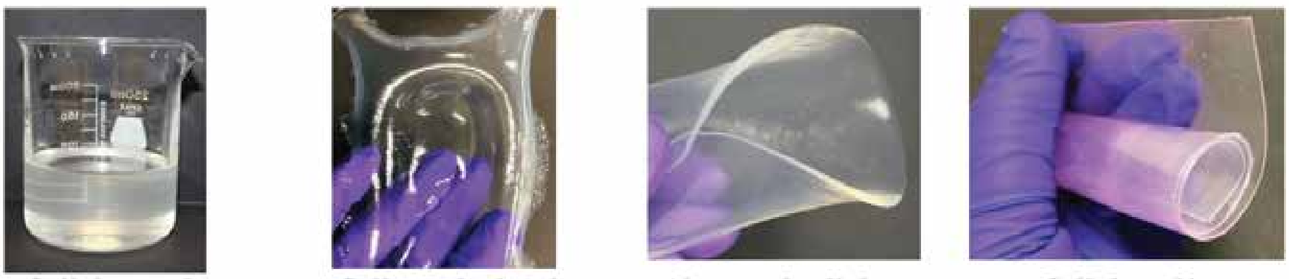
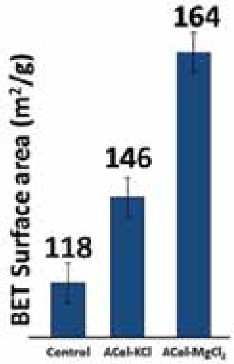


Figure 1.

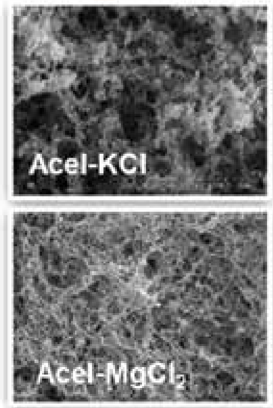
Cellulose porous material could also be prepared by dissolving cellulose in NaOH/water solvent system followed by gelation and drying in supercritical conditions (Parajuli, Acharya, Hu, & Abidi, 2020; Parajuli, Acharya, Shamshina, & Abidi, in press) (Figure 2). Different alkali and alkaline earth metal chlorides with different cationic radii (LiCl, NaCl, and KCl, MgCl2, and CaCl2) could be used to tune the morphological properties of cellulose aerogels.

This allows altering the specific surface area, the pore volume and the pore size distribution. Some applications of these materials could be in oil/water separation, drug deliver, dye adsorption/removal, carbon aerogels, supercapacitors, etc.

Porous cellulose materials



Effects of salt on BET surfrace area



Morphology of the prous materials

Perspectives: Cellulose will continue to attract special interest not only as a renewable biopolymer but as a substrate for materials research. Because cellulose does not melt, the major challenge in converting cellulose to bioproducts is its insolubility in most common solvents. However, the development of the so-called "green" solvents, such as ionic liquids, will open new horizons for the preparation of bioproducts from cellulose.

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Elongation – A new look at an old measurement

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Fiber strength has long been understood to be an important fiber property. Cotton fiber strength directly relates to the amount of damage sustained during ginning (Dever et al., 1988) and how well cotton can be processed at high speeds (Meredith, 2005). Breaking strength is only one of the two material properties that determine how well cotton fiber may withstand processing and handling. Breaking elongation contributes equally to determining the total energy a fiber, or fiber bundle, can absorb before breaking. Breaking strength is plotted on the vertical (y-axis) while breaking elongation is plotted on the horizontal (x-axis), and the area under the "strength-elongation" curve represents the energy required to break a sample.

Elongation was included as a reported parameter in the early instrument tensile property measurements such as the Pressley and Stelometer flat bundle testers (Orr et al., 1955). However, with the adoption of high-speed automated testing such as the High Volume Instrument (HVI), elongation measurements were no longer pursued. Although HVI type instruments can report breaking elongation values, the variation was relatively high, and there was no calibration material (Taylor, 1986). As a result, the cotton industry and breeders have focused on tenacity (strength) alone and not elongation.

Cotton breeders have made significant advances in improving fiber strength, but little attention has been paid to elongation. One study (Green and Culp, 1990) found that HVI-measured bundle strength had a weak negative correlation with HVI-measured elongation, which led many researchers to focus on strength instead of elongation to avoid potentially producing varieties with lower HVI strength. However, more recent studies have found that breeding for elongation can lead to rapid positive improvements in fiber properties due to previously untapped genetic diversity (Benzina et al., 2007; Ng et al., 2014).

To fully take advantage of the potential of elongation, the HVI must be calibrated for elongation measurements. Researchers at the Fiber and Biopolymer Research Institute (FBRI) at Texas Tech University (Lubbock, TX) developed a set of HVI elongation calibration cotton materials and a correction procedure to implement the calibration (McCormick et al., 2019). The calibration procedure was recently validated through an international round-test (Delhom et al., 2020). To be useful, the results for elongation must be consistent within and across instruments and operators. The round test examined six different cotton samples tested daily across 10 HVI lines for a week (Figure 1). The data clearly illustrates that the variance between HVI lines, without calibration, is too great to compare results between instruments.

However, after the calibration is performed, the agreement between HVI lines is significantly improved. The variance of elongation is also considerably reduced (Table 1). Before calibration, the elongation measurement had a 34.05% coefficient of variation; however, calibration reduced that to 5.22%.

Examination of elongation of cotton is in the early days of a renaissance, and there are many unknown characteristics for elongation. For example, for the use of HVI-type instrumentation in cotton classification, there are equipment precision specifications and calibration tolerances provided for the standard measured fiber properties, as shown in Table 2 (Cotton Incorporated, 2018). It is not yet established what the expected precision or tolerances are for elongation.

Additionally, the cotton samples selected for use in calibration are chosen based on relatively low variance within the property of interest.

The samples in this study were selected to represent a wide range of mean elongation values, and no consideration was given as to the amount of variance within the sample.

The six cotton samples used in the round test had a range of HVI elongation values, after calibration, of 4.72% to 9.55%. The lower elongation samples tended to have lower variance, but it was not an absolute trend. The higher elongation selections displayed higher variance within and across HVI lines.

It has been demonstrated that elongation is a good predictor of processing quality (Faulkner et al., 2012), but there is much to be studied to understand elongation. The availability of elongation calibration materials and protocols is the first step in reviving the inclusion of elongation as a common cotton characteristic. It is necessary for breeders to continually advance the quality of cotton to remain competitive with man-made fibers. Elongation allows untapped genetic diversity to be accessed and provides for a new approach to examining fiber-machine interactions.

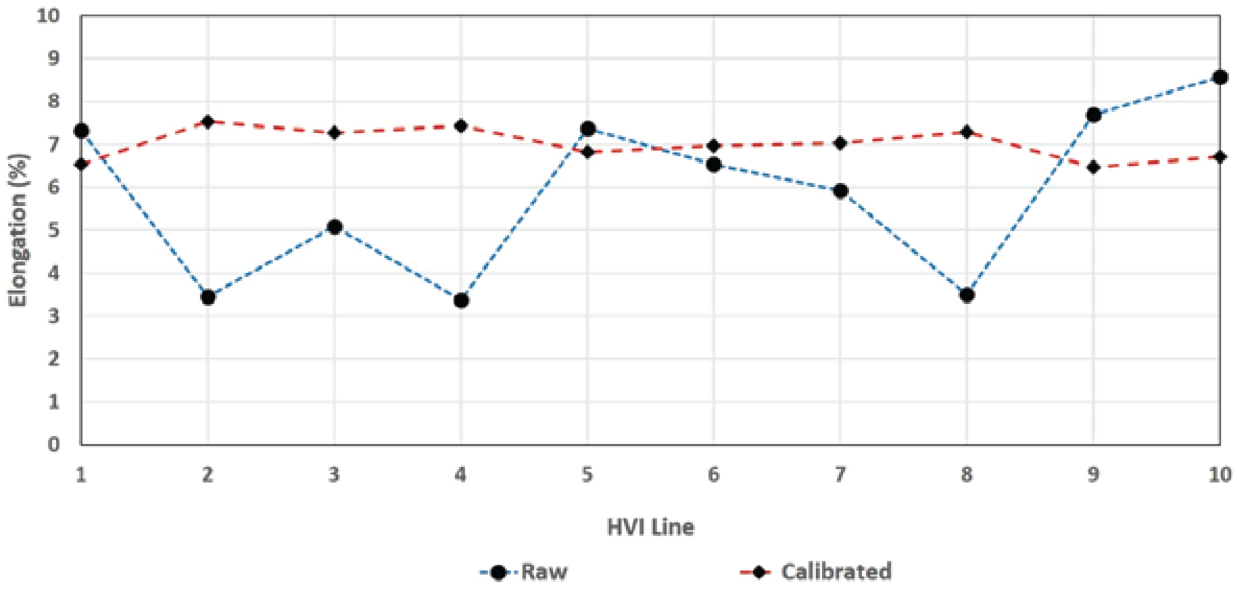

Figure 1. Mean of all cottons and days by HVI line – raw and calibrated

Table 1. Variance of fiber property measurements for six cottons across ten HVI lines

Property	Average CV(%)
Micronaire	1.73
Strength	3.41
UHML	1.32
Uniformity Index	0.86
Elongation (Uncalibrated)	34.05
Elongation (Calibrated)	**5.22**

Table 2. Equipment precision specifications and calibration tolerances for HVI testing of cotton

Property	Precision Specification	Calibration Tolerance
Micronaire	± 0.100	± 0.100
Strength (g/tex)	± 1.00	± 0.500
UHML (mm)	± 0.305	± 0.178
Uniformity Index (%)	± 0.800	± 0.700

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Seeding Choices for Preferred Fiber Farming Systems

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Interest in sourcing more environmentally friendly cotton fiber continues to grow among manufacturers, brands, retailers, and customers. Second annual report of 2025 Sustainable Cotton Challenge (Textile Exchange, 2020a) indicates different terminology, such as "preferred cotton" or "sustainable cotton" may be used, challenge signatories and partners are committed to continuous improvement and achieving positive impact by encouraging programs that do "less harm" toward environmental and social outcomes. This resource details several preferred cotton initiatives around the world, their farm requirements, verifications systems, and/or certification mechanisms. Recognized initiatives have a clear code, guideline, or standard that, for a base line introduces improved production practices across core areas such as water and integrated pest management. The latest initiative, U. S. Cotton Trust Protocol, is grown to code under existing mandatory federal regulations and 2^{nd} or 3^{rd} party verified, field print calculator. Other initiatives introduce regenerative soil practices, and one of the oldest and most stringent benchmarks is 3^{rd} party-certified organic production system practices. The Organic Foods Production Act (OFPA) for Food and Fiber enacted under Title 21 of the 1990 U. S. Farm Bill established uniform national standards for production and handling of food and fiber labeled as certified organic. Rules for implementing the legislation came out in 2000, and standards for certification established in 2002.

The United States Department of Agriculture National Organic Program (NOP) sets national standards that are reviewed and revised by the National Organic Standards Board. However, in 1987 when Texas Department of Agriculture established an official state label, Texas was first to recognize market potential of organic cotton (Apodaca, 1992) and offer certification of organically grown food and fiber. By 1993, enough farmers in Texas were producing organic cotton to form the Texas Organic Cotton Marketing Cooperative. Currently, any 3^{rd} party organic certification in the United States must follow at least NOP standards. Certified organic cotton today remains less than 2% of global production (Textile Exchange, 2020b). U. S. organic cotton production is concentrated in the Southern High Plains of Texas (Figure 1), where temperature and elevation limit insect pressure, semi-arid climate makes weed and vegetative plant growth manageable, and killing freeze defoliates the crop after maturity and before harvest each year. Whole fuzzy cotton seed not destined for planting is marketed as feed to organic dairies in the region. Texas organic cotton farmers also grow other organic crops in rotation with cotton such as peanuts, wheat, corn, grain sorghum, peas, and sesame. Farmers deeloped innovative production methods with little technical assistance other than their own trial and error. Experienced organic cotton farmers on the Southern High Plains can produce comparable yield and quality to conventional cotton in a good year.

Figure 1. Organic cotton yield trial near Lubbock, TX

The NOP disallows use of planting seed cultivars developed using excluded methods including gene deletion, gene doubling, introducing a foreign gene, and changing the position of genes when achieved by recombinant DNA technology. As most planting seed providers shifted toward offering transgenic varieties in the mid-1990s, seed security became an issue for the fledgling organic cotton industry in Texas. The OFPA also established the Organic Research and Extension Initiative (OREI), and first grants were awarded through National Institute for Food and Agriculture in 2004. In 2010, the Texas A&M AgriLife Research cotton breeding and entomology programs in Lubbock were funded to develop thrips tolerant germplasm, since organic cotton farmers' options for early-season insect injury are limited (Wann et al., 2017).

Organic cotton farmers in Texas had few planting seed options except to catch some of their own seed from older, no longer commercially available cultivars without transgenic traits, e. g., FiberMax 958, under the 1994 farmer exemption of the Plant Variety Protection Act. However, since the Southern High Plains is one of the most concentrated cotton production regions in the world, unintentional gene flow, especially since pollinators are meant to be protected in organic production, had the potential to create trace adventitious presence of genetically engineered traits even though the farmers did not plant a cultivar developed using recombinant DNA technology. Quantitative testing for the many genetically engineered traits approved in U. S. cotton is complex and expensive, on top of existing organic certification costs. Addressing organic seed production issues became a top research priority.

Texas A&M AgriLife Research cotton breeding programs in Lubbock and College Station received an OREI grant in 2014 to develop cotton for organic production with a distinct morphological marker (okra-leaf) so outcrosses or proliferation of normal leaf cotton plants, assumed to be transgenic, could be visually detected before flowering and removed (Figure 2). Other breeding objectives are boll type to minimize crop loss before freezing, good fiber quality stability, thrips tolerance, and root systems conducive to environmental resilience. Complex crosses with previously developed sources with these characteristics were made in 2014, and following four generations of screening for fiber quality, drought resilience, boll type, and bacterial blight, and two years of multi-location replicated performance testing, two candidate okra-leaf cultivars for organic production will be submitted for release in 2021 (Table 1).

Figure 2. Organic crossing block at the Texas A&M AgriLife Research and Extension Center greenhouse

Table 1. Two organic production candidate okra-leaf cultivars compared to standard FM 958* grown in irrigated replicated performance test** at Texas A&M AgriLife Research and Extension Center in Lubbock, 2019.

Designation	Yield (kg ha^{-1})	Percent Lint (%)	Micronaire (units)	Length (mm)	Strength (kN m kg^{1})	Elongation (%)
CA4014 O	1,490	38	4.7	29.2	313.6	6.9
CA4015 O	1,598	37	4.5	29.2	319.5	5.4
FM 958	1,524	37	4.8	28.4	309.7	6.1

*FM 958 is predominant cultivar currently grown by U. S. organic cotton farmers according to 2020 USDA-AMS 'Cotton Varieties Planted' publication and Organic Cotton Market Report. Candidate cultivars have similar crop maturity and boll type to FM 958.

**test included 20 total entries, 16 experimental strains and four commercial cultivar checks, with average yield of 1,441kg ha^{-1}, 13.8% coefficient of variation and 234 kg ha^{-1} LSD.

In response to growing interest, Texas A&M scientists have initiated other projects related to regenerative agriculture methods and developed an undergraduate course in organic agriculture production. An organic and specialty crops breeder was hired at the Vernon Center in 2020 and a Texas Extension Organic Program Specialist was hired at the Stephenville Center in June 2021. As interest and demand for sourcing preferred cotton fiber grows, expect research innovations inspired by pioneering Texas organic cotton farmers to flourish.

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Plastic Contamination: What is being done at the cotton gin to address the issue?

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Today, over half of the U.S. cotton crop is harvested by state-of-the-art, highly efficient machines (John Deere cotton harvesters, 7760, CP690, and CS690, Deere and Company, Moline, IL) that form cylindrical (round) seed cotton modules which are wrapped in linear low-density polyethylene (LLDPE) plastic film. The plastic serves to protect the cotton inside the module from environmental effects such as wind and rain while restraining the seed cotton in a compact, dense cylindrical form suitable for efficient transportation from field to gin. As adoption of this revolutionary cotton harvesting and moduling technology has increased, so has the occurrence of plastic contamination in lint bales. USDA-AMS cotton classing offices are finding that the primary source of plastic contamination showing up in marketable U.S. cotton bales is plastic from the cylindrical modules created by these systems. Despite diligent efforts by cotton gin personnel to remove all plastic wrap before processing, plastic still finds its way into the cotton gin's processing system at a level ten-fold greater than before the advent of round modules.

Bales with plastic contamination receive substantial price discounts from merchants and mills, as reflected in the -4000 point per pound (-1815 pts per kg) spot quotation discount for USDA-AMS plastic designations 71 and 72. The consistent discount for plastic contamination on spot market quotations has increased the CCC Loan discount for 71 and 72 designations to -3130 and -3240 points per pound (-1420 and -1470 per kg), respectively. With the increase in plastic contamination along with the financial impact on producers and mills alike, detecting and removing plastic contamination has rapidly become a top priority of the U.S. cotton industry.

To mitigate this loss of quality and profit resulting from plastic contamination, USDA-ARS (ARS) engineers working at the Cotton Production and Processing Research Unit in Lubbock, TX and the Southwestern Ginning Laboratory in Las Cruces, NM developed the Plastic-Inspection-Detection and Ejection-System (PIDES) technology that efficiently detects and removes plastic contamination during post-harvest processing of cotton. The technology is a low-cost, "bolt on", detection and removal system built using off-the-shelf parts, such as cell phone processors and cameras, in order to achieve high-speed, real-time image processing (Fig.1). This detection system coupled to a pneumatic ejection system (Fig. 2) blows plastic contamination out of the process stream, thereby preventing it from contaminating marketable fiber.

The first obstacles tackled by the ARS design team were identifying where in the ginning process that sensors could be placed to detect contaminants and what low-cost sensing technologies could be used. Since a typical U.S. cotton gin can process in excess of 65,000 lb of cotton in an hour (29,484 kg/hr), the detection and removal system must be able to identify the plastic contaminant and remove it at this rate. Likewise, the system needs to be able to see the plastic in real-time in an area where the cotton is the most singulated. An examination of the ginning process revealed the gin-stand feeder apron as a potential location. An advantage to this location is that the depth of cotton flow is very shallow and uniform, but a major disadvantage is the short residence time of cotton on the apron slide. Detection and removal might be possible on the feeder apron, but keen engineering would be required to develop a system to identify contaminants in real time and actuate a removal system given the short time duration of cotton on the apron. It was determined that all steps associated with contaminant detection (i.e. image capture and digital signal processing) would need to occur in about 25 milliseconds, to allow enough time for a pneumatic system to eject plastic from the cotton at the base of the apron. Another design challenge addressed by the team was the need to keep the Machine-Vision optics clean when operating inside a high-dust environment under the wide-ranging temperature swings encountered in cotton gins. The final design challenge was cost. Unlike similar systems used in edible foods like grains, nuts, or vegetables, which can sell in the range of $10,000 to $20,000 per linear foot, this system needed to be less than half that price. Essentially, we needed traditional Machine-Vision performance out of a system costing significantly less than what traditional Machine-Vision systems cost.

To solve the design challenges, the ARS team identified several embedded processors and low-cost imagers, commonly utilized in cell phones, in an effort to develop a low-cost Machine-Vision system that is fast and robust enough to identify contaminants at the feeder apron in a cotton gin. Custom low-level source code was developed (10,000 lines of code) to ascertain if, and which ones, of these cell phone processors and imaging sensors would be most suitable for use in an industrial environment while offering the performance required for real-time detection fast enough to allow time to fire the appropriate solenoids before the rapidly traversing cotton and plastic slipped into the gin stand. The team was successful, developing a complete working system with the requisite performance on a budget that in end was 1/30 that of a traditional machine vision system. Two innovations helped achieve this goal – the use of a two-dimensional color space, and a novel negative classifier look-up table, that was implemented in low level C++ language: separating the colors into the more manageable 2-dimensional a* b* color space, and ignoring the brightness channel (L*), reduced processing time; comparing the image to a two-dimensional 256 x 256 look up table that only had cotton values meant anything not there was “not cotton,” and would be rejected (since it is difficult to predict what color contaminating plastic might be). The final design’s image acquisition and processing speed was fast enough to allow time for the custom pneumatic ejection system to respond when plastic was detected and achieve high accuracy ejection.

The new PIDES system was developed, tested, and successfully transferred under a Cooperative Research and Development Agreements (CRADA) between ARS and Industry Partners, process-engineering firm Bratney Company with assistance from cotton ginning equipment manufacturer Lummus Corporation, in less than two years, quickly addressing one of the most critical issues now facing the cotton industry.

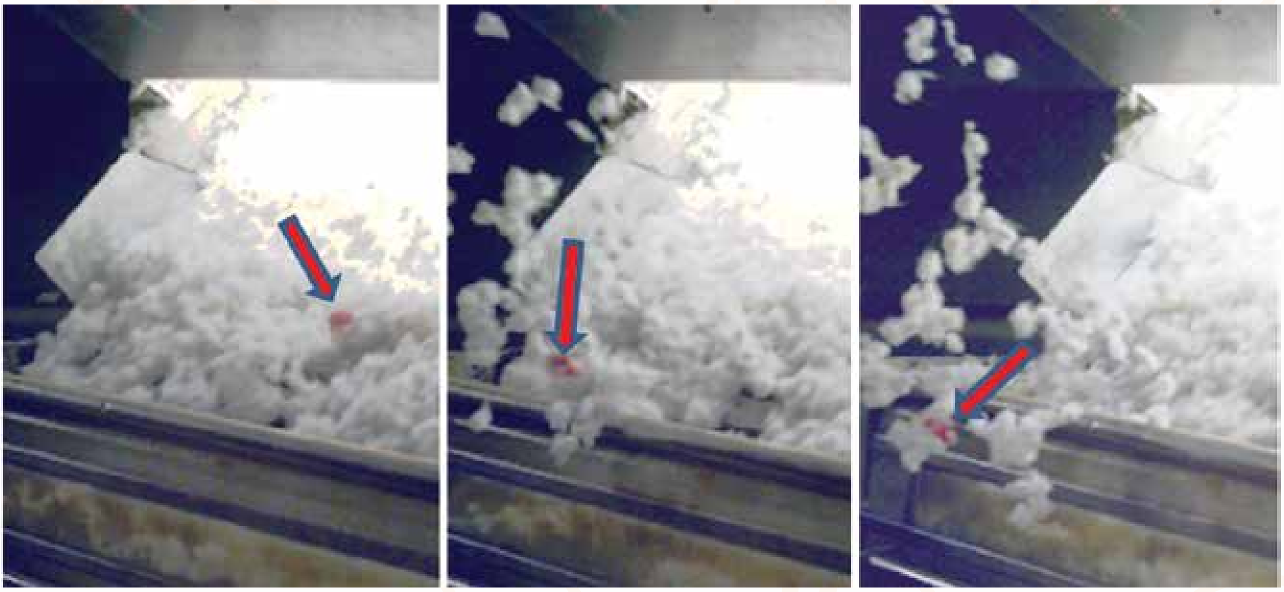
The Industry Partners have branded this system as the Visual Inspection and Plastic Removal (VIPR™)system and the bolt on unit is for sale (Figs 3, 4, and 5). VIPR is integrated into some cotton gins, with more expected in near future. The VIPR technology has shown augmented efficiencies of over 90% in preventing plastic module wrap from getting into cotton bales. This is only one of several technologies being developed by U.S. government and university research institutions to address plastic contamination concerns in cotton. The U.S. cotton industry takes seriously its commitment to provide one of the cleanest cottons in the world.

Figure 1. The PIDES individual camera unit without cover (left) and with cover showing the air knife to keep camera lens clean (right).

Figure 2. The PIDES air ejection solenoids under lower feeder apron (left) and top view showing the air knife ejection device at the end of the feeder apron (right).

Figure 3. VIPR system being installed in a commercial cotton gin.

Figure 4. VIPR system during operation shown above gin stand (left) and images of contamination detected and removed from the process stream before the cotton entered the gin stand (right).



a. b. c.

Figure 5. Plastic-Inspection-Detection and Ejection-System, being sold as VIPRTM, in operation. Figure 5a shows target just before ejection, after detection. Figure 5b, shows target during ejection process and Figure 5c shows target after ejection is complete.

U.S. Cotton Trends and Future Breeding Goals

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U.S. Upland cotton quality trends have shown consistent growth over time (Figures 1-4). Historical gains in fiber length and strength have not only made a profound impact on the textile industry but have attained a stage that uphold premium quality in national U.S. averages. A leading global cotton exporter, the U.S. produces approximately 20 million bales of cotton each year, which are classed by the USDA-Agricultural Marketing Service for quality to enable fair marketing and are an integral part of the U.S. supply chain.

While the U.S. boasts superior fiber strengths and lengths over the past decade, there was a time when discounts were taken for these traits (Figures 5 and 6). Breeding efforts were charged with a push from the public and private sectors that drove these numbers upward. In the 2020 crop year, at least 78% of U.S. bales enjoyed premiums on strength, with less than 1% being discounted (USCROP™). Breeding efforts and subsequent gains have changed the dynamic of cotton against synthetic fibers by improving quality through the development and utilization of cutting-edge research tools. Yet, challenges still face the U.S. in the fiber quality world. In 2019, discounts amounting to 7 million USD were taken for length uniformity index (LUI) and 24 million USD in micronaire (USCROP™). In 2010, 5 million USD in LUI losses and 49 million USD in discounts to micronaire were classed.

LUI derived from the mean length and upper half mean length as calculated from the fibrogram generated by Uster's High Volume Instrument (HVI®) machine has, unfortunately, stagnated over the years (Figure 3). LUI is an indication of the uniformity and presence of variation in the length of the fiber sample in a cotton bale. An aggressive approach in tackling LUI was spearheaded in 2017 by Cotton Incorporated with a series of research projects while creating widespread public and industry awareness. From understanding the cause for LUI stagnation to pushing for its improvement, efforts have commenced towards developing new phenotyping methods, breeding goals and conservation of LUI at the gin. Research on the critical aspects of the HVI fibrogram could greatly benefit cotton breeders in being able to address genetic effects for length distribution affecting uniformity parameters without having to run Uster's Advanced Fiber Information System (AFIS®).

Fiber micronaire, a trait provided by HVI®, is an indicator of both the maturity and fineness of cotton but is not a true measure of either. A premium for micronaire is awarded when it is optimal in the range of 3.7 – 4.2 units (keeping with staple and leaf grades). While micronaire shows a positive trend in averages for U.S. upland crop (Figure 4) it is often discounted, creating room for improvement. AFIS® provides direct measurements of maturity and fineness.

Standard fineness can be calculated from that data by normalizing fineness against the maturity ratio to provide the closest measure of biological fineness (Hequet et al., 2006). Fiber maturity is widely known to be environmentally regulated, but there is evidence in literature suggesting genetic components to biological fineness (Chee and Campbell, 2009). In theory, if we reduce the fiber diameter of upland cotton, we give the fiber a competitive advantage at maturing to near perfection even under sub-optimal environmental conditions. The hurdle with directing selection efforts towards improving standard fineness is that AFIS® is expensive because it is slow. An approach to associate genetic components with AFIS® fineness and standard fineness has been initiated by developing populations and screening across environments to identify and eventually develop molecular markers for ideal biological fineness. This can provide a high throughput pre-screening ability within breeding populations that could still thrive under stressful environmental conditions from the micronaire perspective. The more fine and mature fibers we fit in a fiber cross-section, the better is our ability to manufacture fine, premium quality yarn.

The U.S. cotton industry, public and private, make for one of the finest research teams in the world. Given the multitude of historical gains across yield, fiber quality, agronomic management, and engineering tools, there is promise that in the future we are set for a full profile gain in fiber quality, encompassing LUI and micronaire. The global research world constantly pushes its limits to make gains and continue to let the natural cotton fiber prevail against all challenges.

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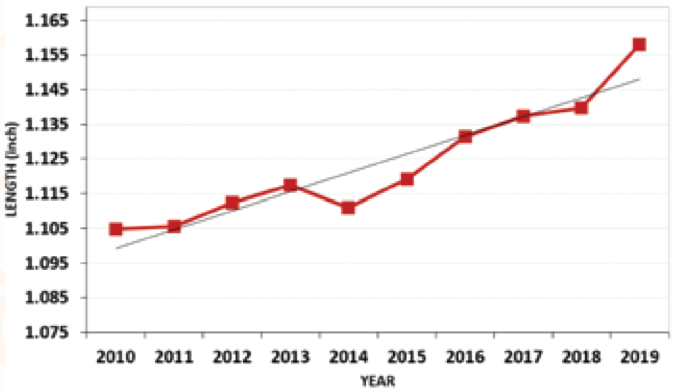

Figure 1: U.S. Fiber Length (2010-2019) Source: USCROP™

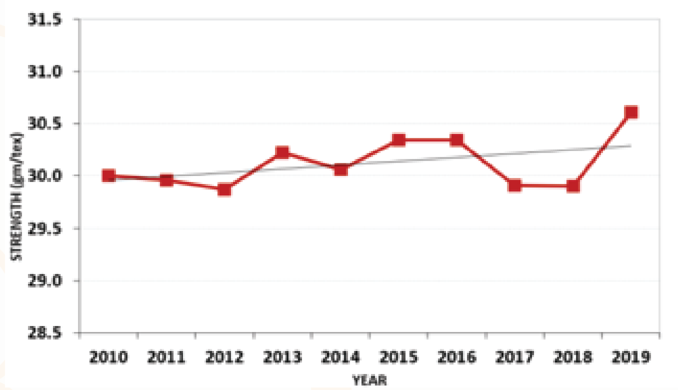

Figure 2: U.S. Fiber Strength (2010-2019) Source: USCROP™

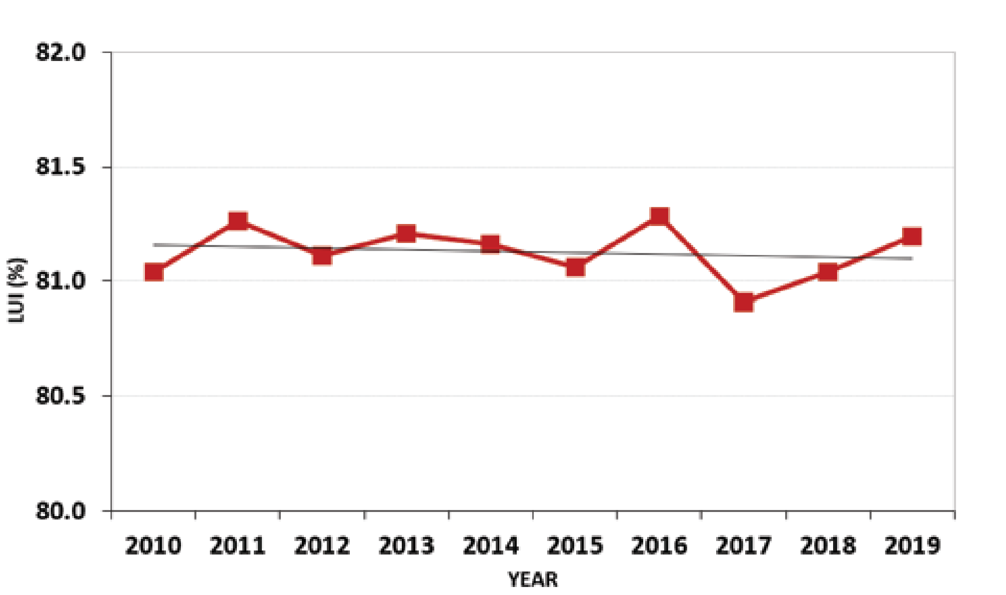

Figure 3: U.S. Fiber Length Uniformity Index (2010-2019) Source: USCROP™

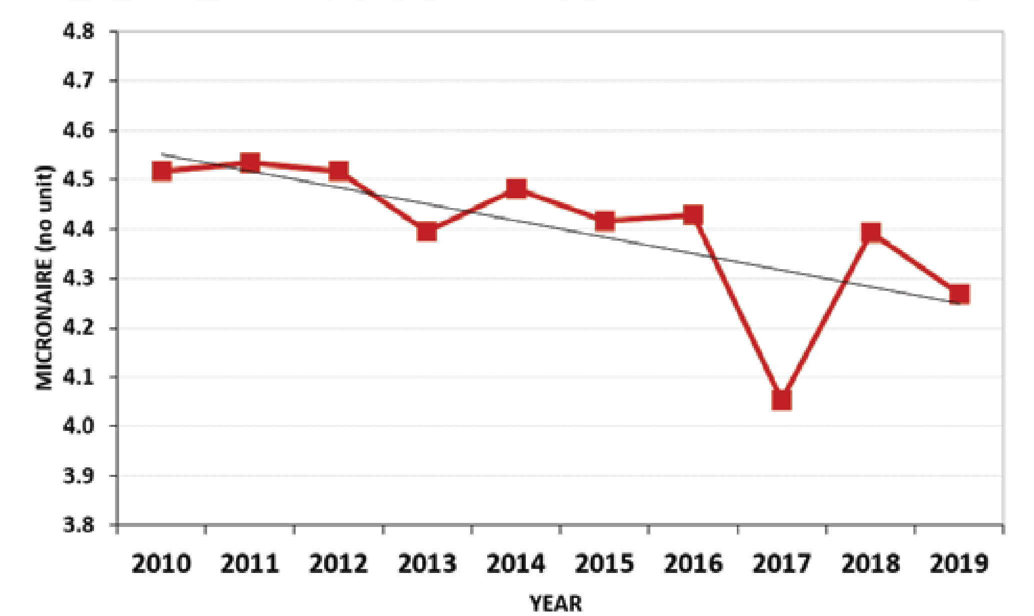

Figure 4: U.S. Fiber Micronaire (2010-2019) Source: USCROP™

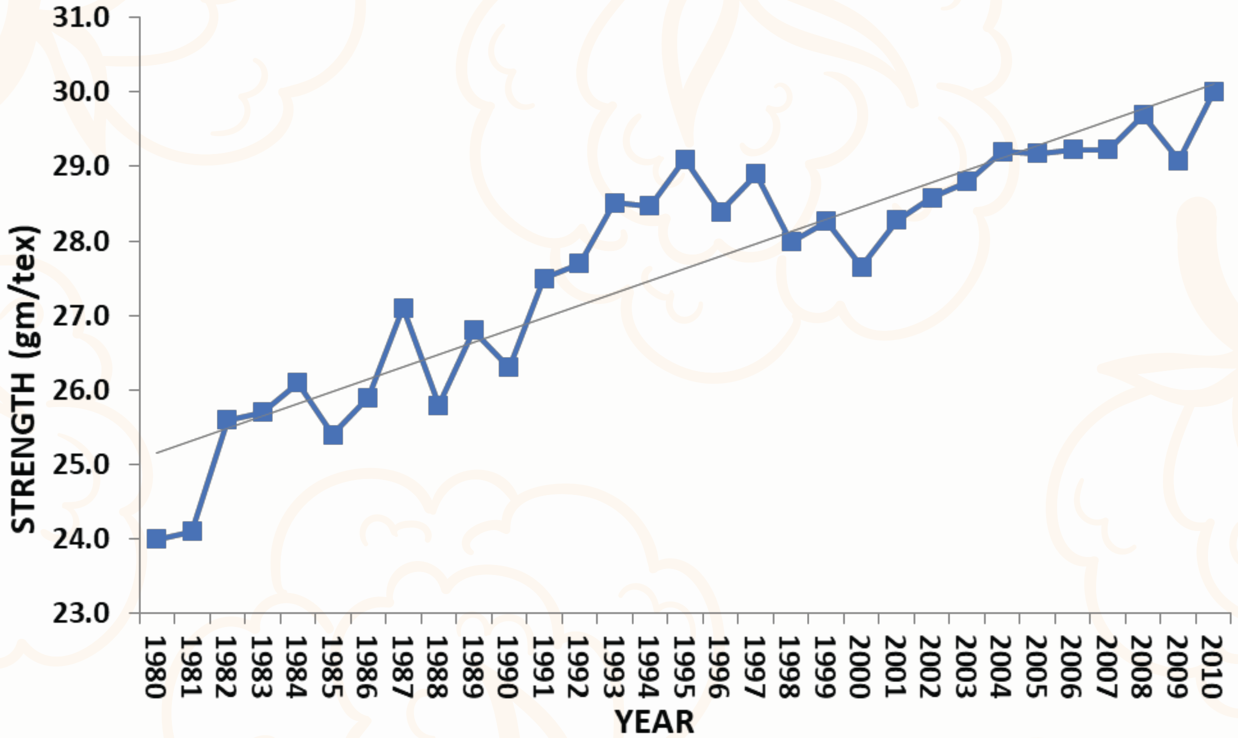

Figure 5: U.S. Fiber Strength Historic Trend (1980-2010) Source: USCROP™

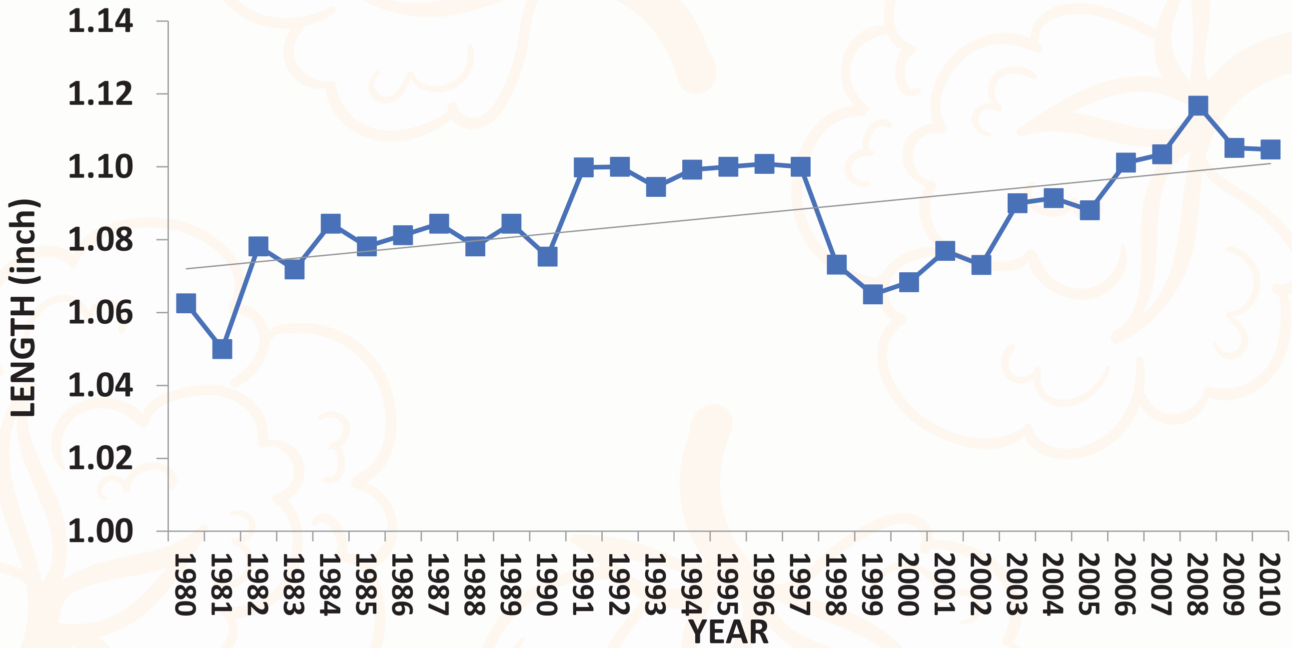

Figure 6: U.S. Fiber Length Historic Trend (1980-2010) Source: USCROP™

DEVELOPING IMPROVED LENGTH AND STRENGHT IN UPLAND COTTON

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A number of cotton quality traits impact yarn quality and the type of spinning platform on which the fibers can be spun as well as the size of yarn that can be produced. Deussen (1993) suggested that fiber strength, upper half mean length (UHML), friction properties, uniformity of fiber lengths, maturity, and fineness impact spinning efficiency. May and Green (1994) suggested that fiber strength as fiber bundle strength (FBS), was a primary fiber quality property impacting spinning.

The efforts by Texas A&M AgriLife to improve fiber traits date to at least the 1970s when breeders in the U.S. initiated efforts to make significant improvements in FBS to overcome the inherent weakness of rotor spun yarn as spinners moved to replace ring frames with rotor frames. Cultivars grown by U.S. producers at that time exhibited FBS around 20 g/tex. By 2001, some commercial cultivars entered as regional or national standards in the USDA National Cotton Variety Tests (https://www.ars.usda.gov/southeast-area/stoneville-ms/crop-genetics-research/docs/national-cotton-variety-test/) exhibited FBS at 27 g/tex (excluding the Acala standards which exhibited 27 g/tex much earlier). In 2020, FBS reported in the Cotton Cultivar Trial at College Station, TX averaged 32 g/tex, about a 60% improvement compared with 1970.

Today, the cotton spinning industry is again faced with a new technology, air jet or Murata Vortex Spinning (MVS). This next generation of spinning technology will produce yarns at speeds over 20 times faster than ring (Gunaydin and Soydan, 2017). Current expectations are that the MVS system will require cotton fibers that are longer, stronger, and finer than required for ring or rotor spinning, again putting pressure on the breeding community to develop cultivars with such fiber characteristics (www.muratec-usa.com/machinery/textiles/vortex-spinning-machine, accessed 29 June 2020). The MVS produced yarns have a core of somewhat parallelized fibers that are surrounded by "wrapper" fibers with a direction around the yarn axis similar to ring spun yarn. Thus, fiber friction is reduced in MVS yarn relative to that produced on ring frames and stronger and finer individual fibers will be necessary to produce yarn strengths competitive with ring. MVS requires less maintenance, includes a fully automated piecing system, and eliminates the requirement for the roving process, all, when combined with the increased speed of production, should reduce cost per unit of yarn produced.

Texas A&M Agrilife Research has released a number of upland cotton strains with uniquely improved UHML and/or FBS since 2009 (Smith et al., 2009; Smith et al., 2011; Smith et al., 2014, Smith et al. 2018; Smith et al., 2020).

Our progress since 1989 in developing and releasing germplasm or breeding lines for UHML and FBS is demonstrated in figures 1 and 2.

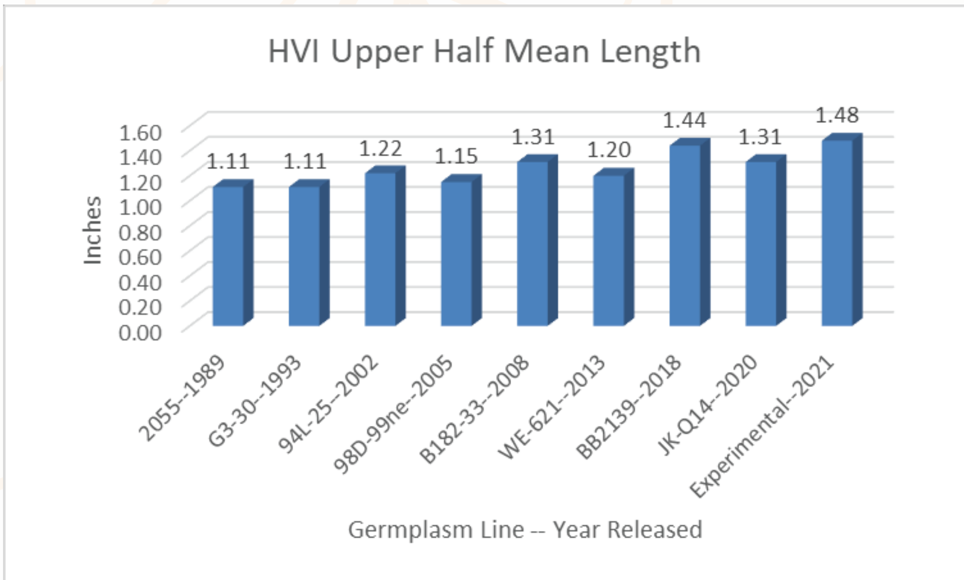

Figure 1. Upper Half Mean Length of selected upland cotton germplasm developed by Texas A&M AgriLife Research from 1989 to 2021.

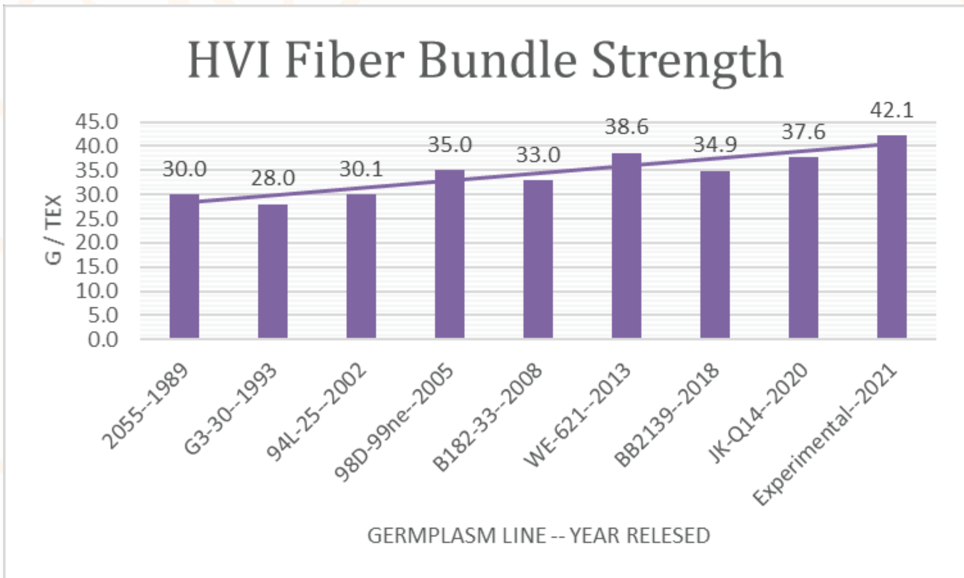

Figure 2. Fiber Bundle Strength of selected upland cotton germplasm developed by Texas A&M AgriLife Research from 1989 to 2021.

Collaboratively with the Fiber and Biopolymer Research Institute at Texas Tech University, we have added spinning evaluation in recent years in an effort to better understand which HVI and AFIS fiber traits have the most impact on yarn quality and appearance, and to guide our decisions on germplasm releases. Such information is critical if breeders are to select fiber types suitable for MVS platforms. A recent example of these efforts was reported in the Journal of Cotton Science (Smith, et al. 2021). In 2019, we compared the carded yarn performance of two of our lines, TAM 06WE-621 and TAM KJ-Q14, with that of Acala 1517-08, a high quality acala cultivar developed by the New Mexico State Agricultural Experiment Station, and Tamcot 73, a standard upland cultivar adapted to Texas. TAM 06WE-621 exhibited slightly shorter UHML than TAM KJ-Q14 and averaged lower Short Fiber Content. Otherwise, the two TAM strains were not different in other HVI and AFIS fiber traits and both averaged 37.5 g/tex FBS. The Acala control averaged slightly shorter UHML and significantly weaker FBS at 33.6 g/tex. All were spun on both a ring frame and a MVS frame. All of the cultivars produced yarn with greater tenacity when spin on the ring frame than on the MVS frame. However, the TAM germplasm lines produced stronger yarn when spun on MVS than Tamcot 73 or Acala 1517-08. Vortex spun yarn from TAM 06WE-621 and TAM KJ-Q14 was equal in tenacity to that produced from ring spinning Tamcot 73 in 2019. The improved TAM germplasm lines equaled or exceeded all appearance parameters for yarn produced on either the ring or MVS frames with Thin50 Places almost non exisitant with TAM 06WE-621. These data suggest that upland cotton cultivars can be developed that are suitable for spinning with the MVS technology.

Recently, the Fiber and Biopolymer Reserch Institute compared the yarn tenacity of 30 Ne carded yarn produced on a MVS 870 frame from commercial bales and from 14 experimental lines in our breeding program. The data are not directly comparable since the fibers were garnered from different sources but included tenacity and Thin50 places for 20 random bales of commercial upland cultivars and 14 experimental lines from Texas A&M AgriLife Research plus Tamcot 73. Figures 3 and 4 again demonstrate progress in developing upland cotton genotypes suitable for vortex spinning.

Traditional plant breeding is a slow and laborours process and progress is dependtent on a number of factors. Desirable genetic variation, industry need, producer and administrative support, and financial resouces are paramount among these factors. Industry accepance of rotor spinning in the U.S. was a major driver in encouraging both private and public cotton breeders to search and produce genetic variation and then select for improved FBS necessary for the production of a desirable yarn for producing products acceptable to the American public. That process, supported by the industry, required about 30 years before the sought after FBS was the standard. Today, the cotton industry may be faced with the same situation where new spinning technology is poised to threaten the cotton fiber industry. The partnership between the Texas A&M AgriLIfe Research Cotton Improvement Program and the Texas Tech Fiber and Biopolymer Research Insititute has demonstrated that genetic diversity exist to improve FBS and UHML to keep upland cotton competitive for spinning on the new MVS frames.

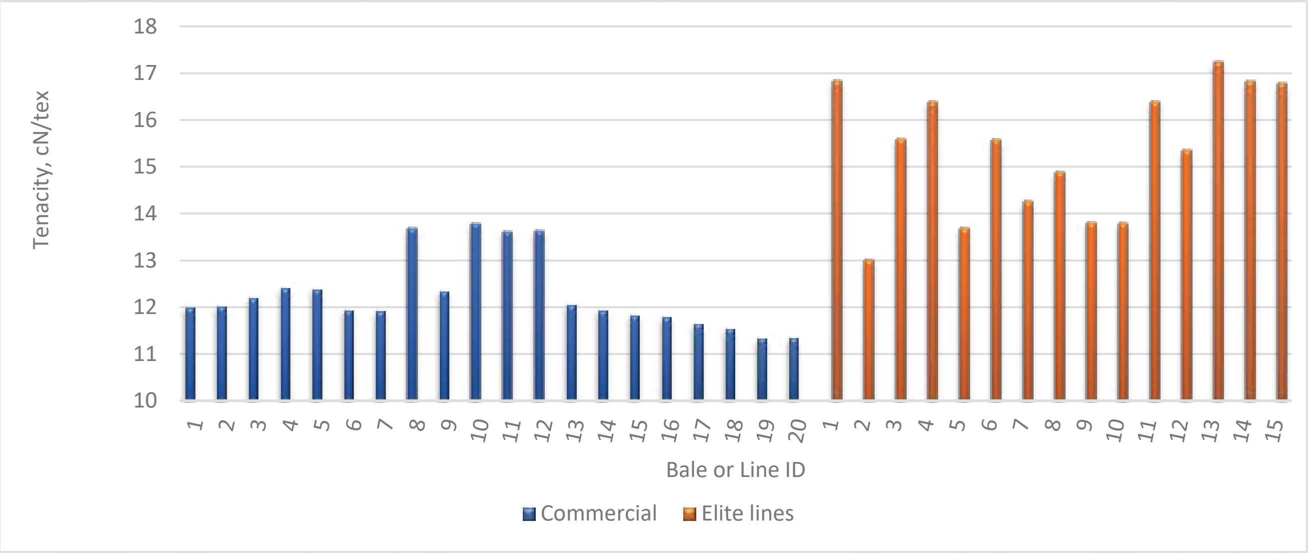

Figure 3. Comparison of MVS yarn tenacity for 20 random upland cotton bales from commercial production fields near Lubbock, TX and 14 experimental lines from Texas A&M AgriLife Research

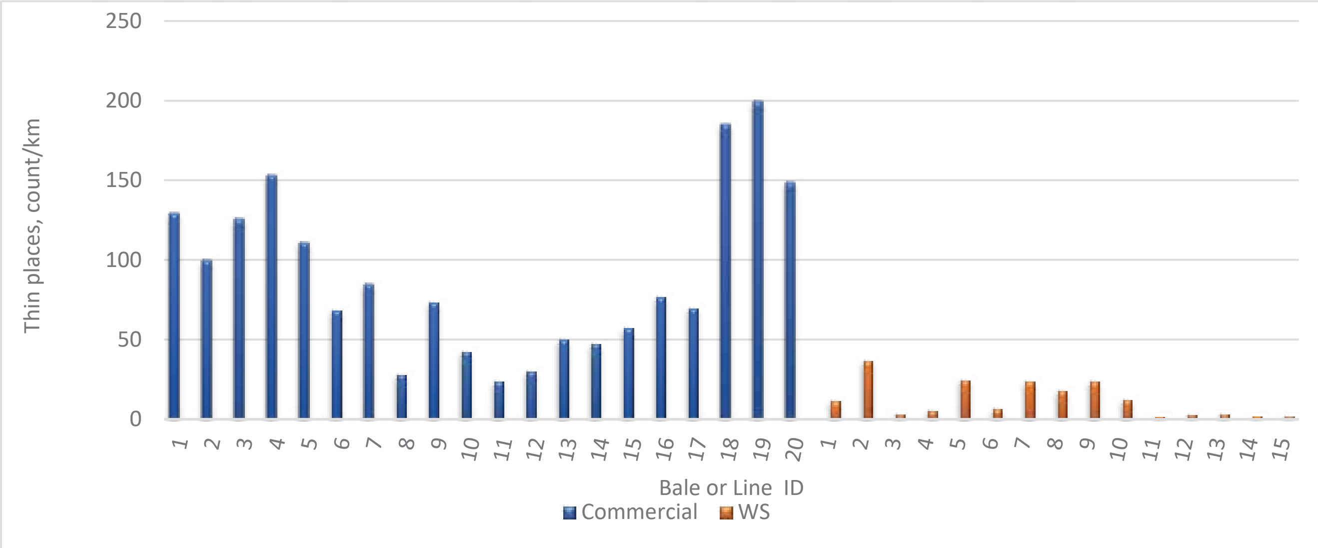

Figure 4. Comparison of MVS Thin50 Places for 20 random upland cotton bales from commercial production fields near Lubbock, TX and 14 experimental lines from Texas A&M AgriLife Research.

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