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Deciphering the fiber quality of *Gossypium barbadense* L. var. *brasiliensis* in La Convención, Cusco, Perú

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Abstract

Background The quality of cotton fiber determines its value in the textile market, influencing agricultural profitability and the efficiency of textile processing. The selection of genotypes with superior fibers is a key factor for genetic improvement programs seeking adaptability and sustainability in the face of climate change. This demonstrates the strategic importance of this plant for sustainable agriculture and the global textile industry. The objective of this research was to decipher the fiber quality of *Gossypium barbadense* var. *brasiliensis* in the native Amazonian communities of La Convención, Cusco-Perú, and to evaluate other critical aspects of native cotton that have not yet been identified. The methodology included non-probability sampling for accessibility, qualitative and quantitative analyses, and multivariate analyses. The fiber length (mm), micronaire index (maturity/fineness), fiber strength (gf/tex), length uniformity index (%), fiber elongation (%), maturation index (%), and short fiber index (%) were the fiber characteristics evaluated using the HVI method in cotton genotypes.

Results Cotton accessions collected from Koribeni (*Gossypium* spp.) and Shivankoreni (*Gossypium barbadense* var. *brasiliensis*) stood out for their fiber quality properties, especially length, strength, and uniformity, which highlights their relevance for advanced textile applications and potential for use in plant genetic improvement programs.

Conclusion These findings reinforce the need to conserve and study these native cotton accessions from the Peruvian Amazon region, which can offer promising perspectives for the textile industry and agricultural biodiversity.

Keywords Cotton, Sustainability, Amazonian communities, Cotton fiber quality

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Introduction

The global importance of cotton as a prominent natural fiber source in the textile industry has not diminished over the decades (Yu et al. 2014, 2021; Zheng et al. 2023).

The textile industry requires a tireless search for high-quality cotton fibers to produce threads, fabrics, and clothing. Therefore, choosing the suitable raw material is essential to ensure the production of high-quality and globally competitive textile materials. Numerous factors, from fiber strength and length to properties such as maturity, fineness, micronaire, and uniformity, among others, are fundamental to determining the quality of cotton fibers (Cotton Incorporated, 2018; INIA, 2012; Siddiqui et al., 2020). The selection and choice of cotton cultivars with high yield potential and extensive applications can affect the economic viability of farmers and the quality of textile products (Barella et al., 1985; Serquen-Lopez et al., 2019; Siddiqui et al., 2020).

The genus *Gossypium* is characterized by its incredible biodiversity and encompasses multiple species that are widely adaptable to different climatic environments and geographic conditions (Weiskopf et al., 2020). This adaptation results in fibers with particular characteristics and different lengths and strength classes, which adds an extra level of complexity and opportunity for the textile industry (Zhou et al., 2022; Johnson et al., 2022; Wang et al., 2023).

In the specific case of cotton native to the Amazon region of Peru, indigenous communities meticulously protecting of textile techniques inherited from previous generations (Morales-Aranibar et al., 2023). These techniques have gone beyond simple manufacturing and entered a universe that combines art, tradition, and sustainability. Currently, cotton fibers native to Peru have been used and processed on traditional handlooms (Morales-Aranibar et al., 2023; Cardoso et al., 2023; Vasquez et al., 2023). This approach improves the physical properties of textile products and has great cultural and historical significance (Ali et al., 2023).

Gossypium barbadense L. var. *brasiliensis* is genetically valuable due to its adaptability to humid environments and unique textile properties. This species of plant has unique characteristics because its seeds are fused together into somewhat kidney-shaped masses; this characteristic has led to its identification as "kidney seed cotton" (Lazo, 2012; MINAM, 2020; Morales-Aranibar et al., 2023). Its fiber length is comparable to that of Tangüis cotton, and its strength is similar to that of American Pima cotton, although the density of the fiber limits certain applications. This cotton plant is ideal for the manufacture of resistant textiles such as uniforms, military clothing, and footwear (Lazo, 2012; MINAM, 2020).

In previous studies, this species was recognized as *G. barbadense* variety *brasiliensis*. It was initially discovered in anonymous samples of cotton of Amazonian origin and with white fibers and developed in the regions of Rupa Rupa and Omagua in Peru (MINAM, 2014, 2017, 2020; Basurto, 2005). Current investigations have confirmed that this species is found in the forest areas of Cusco in the province of La Convención, highlighting its adaptability to the specific environmental conditions of the region since this accession was found in all Amazonian communities in Peru sampled by Morales-Aranibar et al. (2023); however, the origin of this Amazonian cotton remains unknown. Some researchers explained that this cotton plant was moved to the western region of the Andes through Apure River, located in northwest Colombia; however, there is currently no information confirming its center of origin. More studies in Marañón River basin are important for deciphering this origin. These studies will be able to confirm their origin or confirm whether they are intermediate variants between the types of cotton found on both sides of the Andes Mountains (MINAM, 2020; Ano et al., 1984).

One of the biggest challenges for the cultivation of *G. barbadense* var. *brasiliensis* is the limited genetic diversity of cultivated cultivars, which restricts opportunities for significant advances in plant genetic improvement (Viot, 2016; Él, et al. 2021). However, there is a promising source of solutions: native or wild germplasm from Peru. This promising source has a valuable genetic bank that can be fundamental for enhancing the adaptation of plants to adverse climatic conditions, in addition to improving other desired agronomic characteristics (Viot, 2016; Ma et al., 2021). The high genetic potential of this cotton species has not yet been explored in relation to plant genetic improvement strategies. In this way, the proposed approach could significantly contribute to mitigating the current challenges faced by the cotton textile industry.

Recent findings by Morales-Aranibar et al. (2023) revealed the presence of *G. barbadense* var. *brasiliensis* in different native communities in the districts of Echarati and Megantoni in the province of La Convención, Cusco, Perú. These findings reinforce the urgency of intensifying genetic exploration of the unique fiber characteristics of these native cotton accessions, especially because commercial cultivars are losing their fiber bundle strength characteristics (Hinze et al., 2016; Li et al., 2017; Peixoto et al., 2022; Morales-Aranibar et al., 2024). Therefore, conserving and studying these native germplasms has become a priority, especially given recent biotechnological advances and the optimized management of genetic resources (Viot, 2016; Smith et al., 2024).

The objective of this research was to decipher the quality of the white fiber of *Gossypium barbadense* var. *brasiliensis* in the province of La Convención, Cusco, Perú, as well as to evaluate other critical aspects of these native cotton accessions. The results could be relevant to the scientific community, farmers, and the textile industry, as they could provide valuable genetic resources for the development of new varieties and cultivation methods, thus influencing important decisions in cotton conservation, research, and production.

Methods

Study sites and sampling methods

Field sampling was carried out within the Amazonian biodiversity belonging to the province of La Convención, located in the region of Cusco, Perú. Samples of white cotton fiber were collected from the native Amazonian communities of Chakopishiato, Poyentimari, and Koribeni in the Echarati district and from the communities of Miaria, Kirigueti, Timpía, Sensa, Ticumpinía and Camisea, Shivankoreni and Nuevo Mundo in the Megantoni district. The coordinates for these locations are 12°46’3.18"S and 72°34’36.70"W, at and altitude of 1137 m a.s.l. in the Echarati District, and 11°43’3.13"S and 72°56’40.68"W, at and altitude of 334 m a.s.l. in Megantoni District.

The collection and analysis phases extended from April to December 2021. To collect samples of cotton (*Gossypium barbadense* L. var. *brasiliensis*), consent was obtained in advance from the owners of the plots. The collection methodology and identification of samples were performed according to the standardized procedures recommended by Manco-Céspedes et al. (2022), the Ministerio del Ambiente (MINAM, 2020), and the International Union for the Protection of New Varieties of Plants (UPOV, 2018), complemented with guidelines established by Morales-Aranibar et al. (2023).

The samples analyzed were limited to portions of white cotton fibers intentionally selected through non-probability sampling for accessibility or convenience. The reflectance/+b associated with the color was verified in all samples, with values ranging from 7.5 to 21.8. (data not shown). All cotton fiber samples were hand ginned. This approach is justified by the specificity of the study and the need to focus on native Peruvian communities strategically distributed in the districts of Echarati and Megantoni. The selected samples were chosen using the white color of their fibers as a criterion and when collected in the field, phenotypic variations were detected, which are shown in Table 1. Variations were evident in relation to the flower, seeds, bracts, capsules and leaves, and were summarized in Table 1 using 13 descriptors.

Measurement of descriptors

The cotton accessions collected included 16 genotypes of *G. barbadense* L. var. *brasiliensis* and two genotypes of *Gossypium* spp. These two cotton accessions without classification at species level (information that must be obtained from molecular studies), among the eight unknown cotton accessions collected by Morales-Aranibar et al. (2023), were selected for the white color of their fibers. In addition to this characteristic used as a premise in this study (fiber color), we also consider that these two unknown cotton accessions have attributes such as flower length, bract length, bract width, capsule width, length and width of the leaf that differentiate these accessions from the other species initially collected in the study by Morales-Aranibar et al. (2023). A portion of the fiber samples from each of the 18 cotton accessions were used to determine the descriptors described in Table 2.

Fiber quality analyses of all cotton fiber samples were performed using the Uster® HVI (High Volume Instrument) M-1000 equipment under controlled conditions (20 °C and 65% relative humidity) in the Textile Laboratory FILASUR S.A. This laboratory is accredited by the Global Organic Textile Standard (GOTS), Global Recycle Standard (GRS), Better Cotton Initiative (BCI), World’s Finest Cottons (SUPIMA), Peruvian Pima (The world’s softest cotton). A sample of 50 g fibers from each of the native cotton accessions was used. For each fiber sample, the following quantitative descriptors were evaluated: fiber length (mm), micronaire index (maturation and fineness), fiber strength ($gf \cdot tex^{-1}$), length uniformity index (%), fiber elongation (%), maturation index (%) and short fiber index (%).

Statistical analysis

A comparison of the quantitative and qualitative descriptors was carried out considering two groups formed by different cotton species: the first group included two cotton accessions not yet characterized in terms of species [*Gossypium* spp. (unknown cotton)], and the second group included 16 native accessions of *Gossypium barbadense* L. var. *brasiliensis*. The quantitative data were subjected to analysis of variance considering the two groups of cotton species as unbalanced treatments, and the means were compared using the Tukey test at 5% probability. The quantitative data were also subjected to multivariate analysis using the principal component analysis (PCA) method to verify the general variability of the two sets of individuals and combined data for the groups formed, as well as the trends of the groupings and descriptors. The graphs were created using the software Rbio (Bhering, 2017), SigmaPlot 10.0® (Systat Software Inc.), R (R Core Team, 2014), and the “GGally” statistical package.

Results

According to a previous study by Morales-Aranibar et al. (2023), native communities of the Amazon in La Convención, Cusco, Perú, have maintained specific genetic varieties of cotton. However, the quality of the fibers of these varieties has not yet been explored in detail, which is crucial for evaluating whether certain genotypes could be especially valuable when evaluating and characterizing their particularities according to current international standards.

Table 1 Phenotypic information obtained when characterizing 18 white cotton samples collected from native Amazonian communities in La Convención, Cusco, Perú

Samples	Flower			Seeds			
	Spot Color	Flower Color	Position Of The Stigma In Relation To The Anthers	Provision	Feature	Color	Form
A1	Purpura	Daffodil yellow	Above the anthers	Separated	With olive green lint (linter) all over the seed	Dark brown	Oval
A2	Purpura	Pale to creamy yellow	Above the anthers	Separated	With olive green lint (linter)	Dark brown	Ovoid
A3	Purpura	Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A4	Purpura	Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A5	Purpura	Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A6	Purpura	Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A7	Light purple	Cream	Above the anthers	Arriñonada	Low apical and basal lint (linter)	Dark brown	Oval
A8	Purpura	Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A9	Light purple	Cream	Above the anthers	Arriñonada	Low apical and basal lint (linter)	Dark brown	Oval
A10	Purpura	Yellow	Above the anthers	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A11	Purpura	Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A12	Purpura	Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A13	Red	Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A14	Purpura	Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A15	Purpura	Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A16	Purpura	Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Oval
A17	Red	Narcissus Yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
A18	Purpura	Lemon yellow	At the anther level	Arriñonada	Low apical and basal lint (linter)	Dark brown	Ovoid
Acesses	**Bracters**		**Capsules**			**Leaf**	
	Toothing	**Color**	**Shape In Longitudinal Section**	**Features**	**Prominence Of The Tip**	**Presence Of Pusbescence**	
A1	Fino	Green	Narrow elliptical	Smooth with black glands	Fort	Semisheer on leaf underside	
A2	Fino	Green	Narrow elliptical	Semirugose, with little presence of black glands	Fort	No pusbescence on the underside	
A3	Medium	Green	Narrow elliptical	Rough with black glands	Fort	Light on the underside of the leaf	
A4	Rude	Green	Oval	Rough with black glands	Media	Light on the underside of the leaf	
A5	Rude	Green	Oval	Rough with black glands	Media	Light on the underside of the leaf	
A6	Fino-Grosero	Green	Wide elliptical	Rough with black glands	Media	Light on the underside of the leaf	

Table 1 (continued)

A7	Fino	Green	Narrow elliptical	Rough with black glands	Fort	Light on the underside of the leaf
A8	Medium	Green	Narrow elliptical	Rough with black glands	Fort	Light on the underside of the leaf
A9	Fino	Green	Narrow elliptical	Rough with black glands	Fort	Light on the underside of the leaf
A10	Rude	Green	Oval	Rough with black glands	Media	Light on the underside of the leaf
A11	Fino	Green	Oval	Rough with black glands	Media	Light on the underside of the leaf
A12	Rude	Green	Oval	Rough with black glands	Media	Light on the underside of the leaf
A13	Fino	Green	Narrow elliptical	Rough with black glands	Fort	Light on the underside of the leaf
A14	Fino	Green	Narrow elliptical	Rough with black glands	Fort	Light on the underside of the leaf
A15	Fino	Green	Narrow elliptical	Rough with black glands	Fort	Light on the underside of the leaf
A16	Medium	Purple	Oval	Rough with black glands	Media	Light on the underside of the leaf
A17	Fino	Green	Narrow elliptical	Rough with black glands	Fort	Light on the underside of the leaf
A18	Fino	Green	Narrow elliptical	Rough with black glands	Fort	Light on the underside of the leaf

Figure 1 shows the details of branches, leaves, flower, lint, and seeds of the two genotypes belonging to Group 1 (*Gossypium* spp.) collected in Koribeni (Fig. 1A and B) and Poyentimari (Fig. 1C and D) in comparison with a specimen of *Gossypium barbadense* L. var. *brasilensis* (Group 2) collected in Nuevo mundo (Fig. 1E and F). The figure represents the variations that were found in relation to the collection data obtained at the time of collection and phenotypic identification initially established (Table 1).

Qualitative characteristics of cotton fibers

Qualitative assessments were performed based on seven fiber quality properties for a total of 18 cotton accessions collected in the Amazon region of Cusco, Peru (Table 3). In the fiber samples of *Gossypium* spp., exceptional characteristics were observed in terms of fiber length (classified as long), fineness (very coarse), and high strength and elongation, which suggested that these two cotton accessions have high-quality fibers that are suitable for high-yield manufacturing of textile products. These two accessions also had a low short fiber content and high uniformity, and good fiber maturation. In contrast, fiber samples from *G. barbadense* L. var. *brasiliensis* have a wide range of qualitative characteristics, with fibers of medium length and wide variation in strength and uniformity (Table 3). However, the consistency of high strength and elongation across many sampling locations suggests inherent robustness and promising genetic diversity for future use in cotton breeding programs. The varied occurrence of short fibers and maturity indices reflect the complexity of the character and the variations it can manifest depending on adaptability to different locations and the fiber quality that could be exploited to develop superior varieties.

This analysis highlights the importance of strategic genotype selection and conservation for plant genetic improvement, demonstrating the need for additional investigations to fully understand the agronomic and textile potential of these cotton accessions. The variability observed in *G. barbadense* L. var. *brasiliensis* highlights the potential of this species to contribute to cotton biodiversity and crop resilience, as well as to satisfy the specific demands of the textile industry in terms of fiber quality and production sustainability.

Quantitative characteristics of the cotton fibers

The comparison of the quantitative characteristics of fibers from the 18 cotton accessions grouped into two groups [*Gossypium* spp. (group 1) and *G. barbadense* var. *brasiliensis* (group 2)] is shown in Table 4. The results showed that group 1, represented by the two *Gossypium* spp. accessions, had longer staple lengths (17%), greater fiber strengths (35%), and greater length uniformity indices (6%) than did group 2, represented by *G. barbadense* L. var. *brasiliensis*. For the other fiber

Table 2 Qualitative and quantitative descriptors used in the characterization of white cotton samples collected from native Amazonian communities in La Convención, Cusco, Perú

Descriptor	Description qualitative	Description quantitative	Reference
Fiber length/mm	Short fiber	≤ 20.5	(Cotton Incorporated, 2018)
	Medium fiber	20.6–27.8	
	Long fiber	28.6–33.3	
	Extralong fiber	34.9–42.0	
Micronaire (maturity and fineness)	Very fine	< 3.0	(Zellweger, 1999; IMAMT, 2014)
	Fine	3–3.9	
	Medium	4–4.9	
	Coarse	5–5.9	
	Very coarse	≥ 6.0	
Fiber strength/(gf·tex^{-1})	Weak	≤ 23	(Cotton Incorporated, 2018)
	Intermediate	24–25	
	Average	26–28	
	Strong	29–30	
	Very Strong	≥ 31	
Length uniformity index/%	Very low	< 77	(Zellweger, 1999; IMAMT, 2014)
	Low	77–79	
	Intermediate	80–82	
	High	83–85	
	Very High	> 85	
Fiber elongation/%	Very low	< 5.0	(Zellweger, 1999; IMAMT, 2014)
	Low	5.0–5.8	
	Average	5.9–6.7	
	High	6.8–7.6	
	Very high	≥ 7.7	
Maturity index/%	Very immature	< 0.70	(Salazar, 2002)
	Immature	0.70–0.85	
	Mature	0.86–1.00	
	Very mature	> 1.00	
Short fiber index/%	Very low	< 6	(Zellweger, 1999)
	Low	6–9	
	Average	10–13	
	High	14–17	
	Very high	> 17	

quality characteristics, there was no significant difference between the two groups of cotton accessions (Table 4).

Canonical variable analysis of the quantitative data revealed that this multivariate analysis was able to retain 100% of the data variability, with differentiation between groups of cotton accessions (Fig. 2). Group 1 accessions exhibited the highest values of staple length, micronaire index, fiber strength, length uniformity index, and maturity index.

Principal component analysis (PCA) was performed using quantitative data (Fig. 3), considering the two groups separated by species of native cotton accessions. The PCA of the quantitative data demonstrated that there was also similarity in the grouping of accession A3 with the *Gossypium* spp. accessions belonging to Group 1 (Fig. 3). Therefore, this A3 cotton accession is similar to the Group 1 accessions because of its positioning based on qualitative and quantitative data (Fig. 3). The first two principal components explained 77.6% of the variance in the data (Fig. 3). Among the fiber quality characteristics, the greatest contribution was related to the maturity index.

Discussion

The present study provided a detailed evaluation of the fiber characteristics of *G. barbadense* L. var. *brasiliensis* collected at several locations in the Peruvian Amazon

Fig. 1 Botanical material of *Gossipium* collected in Amazonian communities in Peru. **A**, **B** *Gossypium* spp. 1 species unidentified; (**C**, **D**) *Gossypium* spp. 2 species without identification; and (**E**, **F**) *Gossypium barbadense* L. var. *brasilensis*

region, using the HVI method to qualitatively (Table 3) and quantitatively (Table 4; Fig. 3) characterize key aspects of fiber quality. Staple length is a crucial indicator of fiber quality and varies among different cotton accessions (Table 3). Group 1 accessions represented by fiber samples of *Gossypium* spp. accessions collected from Koribeni and Poyentimari differ in their long fibers (>28.6 mm). Similarly, the accession of *G. barbadense* L. var. *brasiliensis* collected from the native community of Shivankoreni also had long fibers (>28.6 mm). Currently, the minimum fiber length required by the textile industry is 28.6 mm (Cotton Incorporated, 2018). The three long fiber length cotton accessions collected in this study have average stable length values between 29 and 31 mm. This observation highlights the importance of these collected native materials since longer fibers allow finer spinning and offer greater strength (Lewin 2006; Cassidy and Goswami, 2017; Orcón et al. 2019).

The fineness or thickness of the fibers was analyzed, highlighting the fiber samples collected from the native communities of Koribeni and Shivankoreni, which have a very coarse fineness. This finding is significant because it indicates the preservation of genes that maintain fiber thickness, a crucial attribute for specific

Table 3 Qualitative properties determined using the HVI method on 18 white fiber cotton accession samples collected from native Amazonian communities in La Convención, Cusco, Perú

Access	Cotton species	Collection site[a]	Cotton fiber quality properties						
			LEN	MIC	STR	ELO	SHO	UNI	MAT
A1	*Gossypium* spp. 1	Koribeni	Long	Very coarse	Very strong	Very high	Very low	Very high	Mature
A2	*Gossypium* spp. 2	Poyentimari	Long	Very coarse	Very strong	Very high	Very low	Intermediate	Mature
A3	*G. barbadense* L. var. *brasiliensis*	Shivankoreni	Long	Very coarse	Very strong	Very high	Very low	Intermediate	Mature
A4	*G. barbadense* L. var. *brasiliensis*	Timpia	Medium	Very coarse	Very strong	Very high	Low	Intermediate	Immature
A5	*G. barbadense* L. var. *brasiliensis*	Camisea	Medium	Very coarse	Very strong	Very high	Low	Low	Mature
A6	*G. barbadense* L. var. *brasiliensis*	Ticumpinia	Medium	Very coarse	Strong	Very high	Average	Low	Immature
A7	*G. barbadense* L. var. *brasiliensis*	Nuevo Mundo	Medium	Very coarse	Very strong	Very high	Very low	Intermediate	Mature
A8	*G. barbadense* L. var. *brasiliensis*	Chacopishiato	Medium	Coarse	Average	Very high	Low	Intermediate	Immature
A9	*G. barbadense* L. var. *brasiliensis*	Nuevo Mundo	Medium	Very coarse	Very strong	Very high	Very low	Intermediate	Mature
A10	*G. barbadense* L. var. *brasiliensis*	Timpia	Medium	Very coarse	Very strong	Very high	Low	Intermediate	Mature
A11	*G. barbadense* L. var. *brasiliensis*	Poyentimari	Medium	Very coarse	Very strong	Very high	Low	Low	Immature
A12	*G. barbadense* L. var. *brasiliensis*	Chacopishiato	Medium	Very coarse	Very strong	Very high	Low	Low	Mature
A13	*G. barbadense* L. var. *brasiliensis*	Miaria	Medium	Very coarse	Very strong	Very high	Average	Low	Mature
A14	*G. barbadense* L. var. *brasiliensis*	Koribeni	Medium	Very coarse	Very strong	Very high	Average	Low	Immature
A15	*G. barbadense* L. var. *brasiliensis*	Shivankoreni	Medium	Very coarse	Very strong	Very high	Average	Very low	Mature
A16	*G. barbadense* L. var. *brasiliensis*	Sensa	Medium	Very coarse	Very strong	Very high	Low	Low	Mature
A17	*G. barbadense* L. var. *brasiliensis*	Kirigueti	Medium	Coarse	Weak	Very high	High	Low	Immature
A18	*G. barbadense* L. var. *brasiliensis*	Shivankoreni	Medium	Coarse	Very strong	Very high	High	Low	Immature

[a] Name of the native community of the Peruvian Amazon. *LEN* Staple length, *MIC* Micronaire, *STR* Fiber strength, *ELO* Fiber elongation, *SHO* Short fiber index, *UNI* Length uniformity index, *MAT* Maturity index

Table 4 Average values of quantitative fiber characteristics for *Gossypium* spp. accessions (Group 1) and *G. barbadense* L. var. *brasiliensis* accessions (Group 2) collected from native Amazonian communities in La Convención, Cusco, Perú

Groups	Fiber quality characteristics						
	LEN/mm	MIC(maturity fineness)	STR/()gf·tex^{--1})	ELO/%	SHO/%	UNI/%	MAT/%
Group 1	29.9 ± 1.5 a	6.9 ± 0.6 a	46.0 ± 3.4 a	11.4 ± 1.4 a	5.0 ± 2.3 a	84.0 ± 1.8 a	0.90 ± 0.02 a
Group 2	25.5 ± 0.6 b	6.4 ± 0.2 a	34.1 ± 1.3 b	14.8 ± 0.6 a	9.0 ± 0.9 a	79.1 ± 0.8 b	0.86 ± 0.01 a
P-value	0.002	0.230	0.014	0.210	0.120	0.006	0.074
CV/%	6.06	8.88	16.2	23.63	37.65	2.63	3.19

LEN Staple length, *MIC* Micronaire, *STR* Fiber strength, *ELO* Fiber elongation, *SHO* Short fiber index, *UNI* Length uniformity index, *MAT* Maturity index

applications in the textile industry. These genes could be fundamental for the development of future cotton varieties that combine durability with other desired properties, thus adapting to different market needs (Zellweger, 1999; IMAMT, 2014; Cotton Incorporated, 2018). However, it should be noted that a micronaire value of 6.90 may be too coarse for the manufacture of finer yarns, which constitutes a point of weakness for cotton accessions native to the Peruvian Amazon. For example, a micronaire of 6.90 and strength above 40 gf·tex^{-1} is very interesting for an 8 Ne yarn, but it may not be suitable for an 80 Ne yarn (IMAMT, 2014; Cotton Incorporated, 2018).

The fiber strength data showed that 83.3% of the samples analyzed had high strength, which is a critical factor for ensuring the durability of the fabrics. This quality is highly valued, as stronger fibers contribute significantly to the longevity and quality of the final product, making them preferable for a wide range of textile applications (Cotton Incorporated, 2018; Serquen-Lopez et al., 2019). The analyses carried out on fiber samples collected from Koribeni (*Gossypium* spp.) and Shivankoreni (*G. barbadense* L. var. *brasiliensis*) showed exceptionally high levels of strength, which highlights the value of the collected materials due to its genetic potential to improve strength in cultivars of commercially grown cotton.

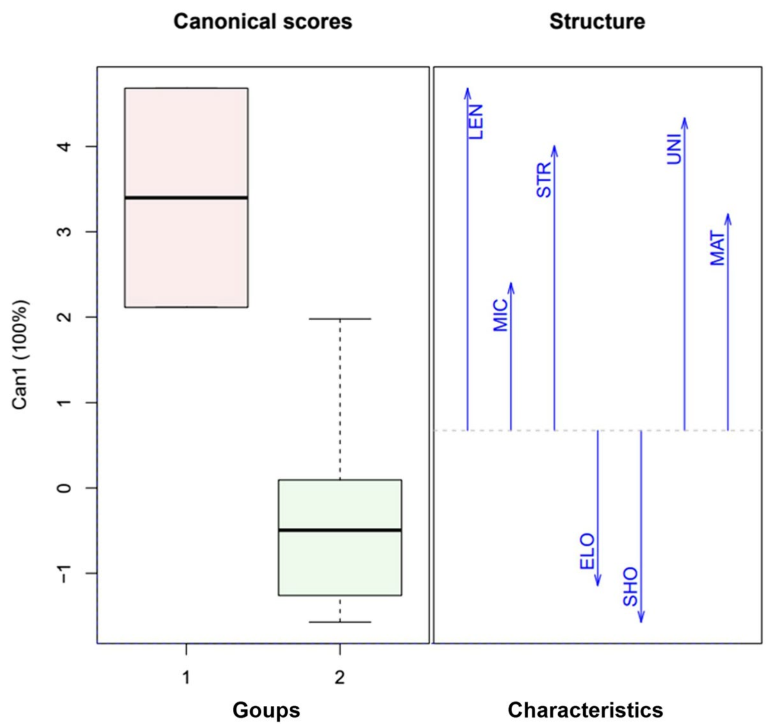

Fig. 2 Canonical variable analysis between fiber quality characteristics of *Gossypium* spp. accessions (Group 1) and *G. barbadense* L. var. *brasiliensis* accessions (Group 2) collected from native Amazonian communities in La Convención, Cusco, Perú. LEN: Staple length. MIC: Micronaire. STR: Fiber strength. ELO: Fiber elongation. SHO: Short fiber index. UNI: Length uniformity index. MAT: Maturity index

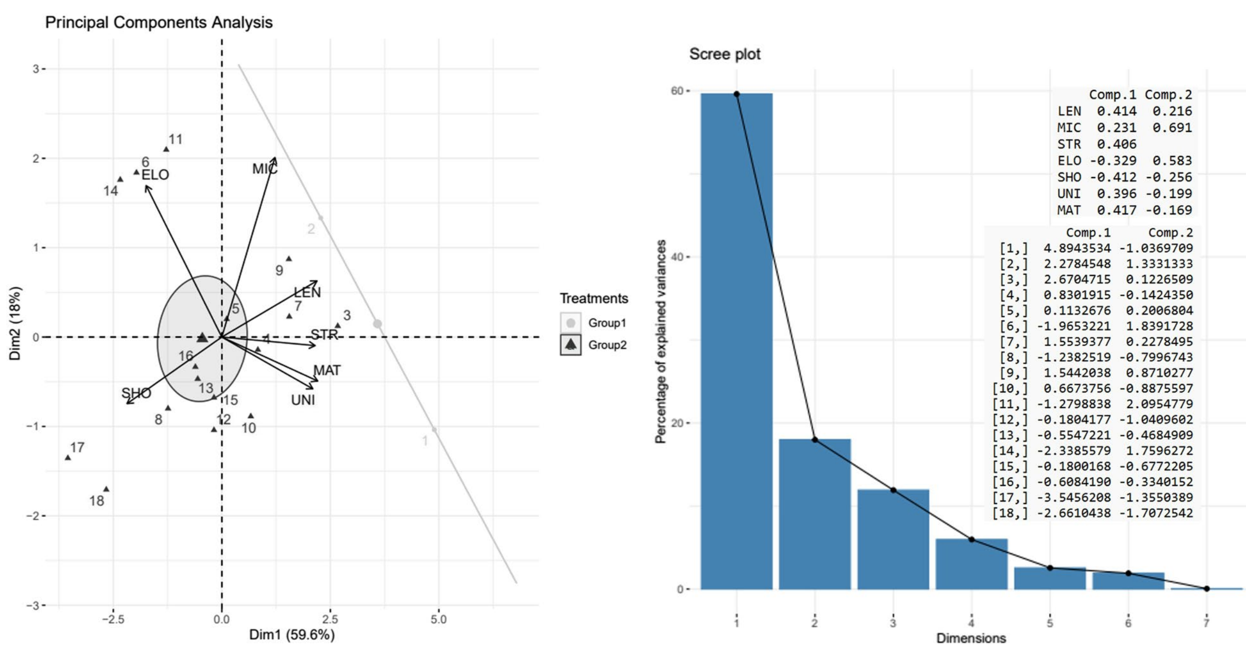

Fig. 3 Principal component analysis of fiber quality characteristics for quantitative data for *Gossypium* spp. accessions (Group 1) and *G. barbadense* L. var. *brasiliensis* accessions (Group 2) collected from native Amazonian communities in La Convención, Cusco, Perú. LEN: Staple length. MIC: Micronaire. STR: Fiber strength. ELO: Fiber elongation. SHO: Short fiber index. UNI: Length uniformity index. MAT: Maturity index. In scree plot, 1, 2, 3 …18 represent the accessions A1, A2, A3… A18, respectively

This discovery highlights the relevance of these samples in the research and development of cotton plants with improved durability characteristics, which is crucial for the textile industry.

Evaluation of fiber elongation, a crucial indicator of tissue quality and flexibility, revealed that both *Gossypium* spp. and *Gossypium barbadense* L. var. *brasiliensis* exhibited high elongation values. This high elasticity capacity is evidenced by fiber elongation values between 11% and 15%, with values above 7.7% being considered fibers with very high elongation capacity (Zellweger, 1999). Cotton samples from fibers with higher elongation (>7.7%) can result in less breakage during fabric production and greater spinning efficiency (IMAMT, 2014). These findings emphasize the importance of both species in the production of high-quality fabrics, suggesting the significant potential for plant genetic improvement focused on elongation, a vital parameter for the textile industry according to previous research (Zellweger, 1999; IMAMT, 2014; Broetto et al., 2013).

The short fiber index was another key aspect evaluated in this study, highlighting the importance of a lower index for obtaining superior-quality textile products, as suggested by Salazar (2002) and López et al. (2018). The results showed diversity in the short-fiber indices among the samples, with Koribeni (*Gossypium* spp.). There are three accessions (A3, A15, and A18) collected from Shivankoreni, with length uniformity index ranged from intermediate (A3) to very low (A15). This characteristic underlines the potential of these varieties to produce high-quality yarns and fabrics, reinforcing the importance of conserving and selecting specific varieties of cotton with low short-fiber indices to improve the quality of the final product in the textile industry.

The evaluation of the uniformity of cotton fibers is essential for characterizing the quality and appearance of the fabric. This study revealed significant variability, from "very high" to "very low". The samples collected from Koribeni (*Gossypium* spp.) were distinguished by "very high" uniformity. This variability underlines the need to carefully select cotton varieties to meet industrial standards, highlighting the importance of properties such as uniformity and fiber maturity in the final quality of textile products, as indicated by authoritative sources in the field (Zellweger, 1999; Salazar, 2002; IMAMT, 2014; Cotton Incorporated, 2018).

In the present study, Koribeni (*Gossypium* spp.) and Shivankoreni (*Gossypium barbadense* L. var. *brasiliensis*) cotton accessions were notable because of their alignment with superior quality standards. In contrast to the findings of former research, these findings illustrate the complex diversity of cotton quality, noting that appropriate selection varies depending on end-use and processing preferences. The importance of carrying out detailed analyses to fully understand these variants is emphasized. The interaction between current research, technological advances, and industrial experience is essential for improving the selection of quality cotton in future research and practical applications (Paz et al., 2019; Morales et al., 2023).

This study enriches the current literature by offering an exhaustive initial analysis of the qualities of *G. barbadense* L. var. *brasiliensis* from Amazonian communities in La Convención, Cusco. It is suggested that future studies adopt quantitative techniques and compare cotton with other cotton forms, thus improving our understanding of the properties and potential for different industrial uses of cotton.

Research on the fiber quality of *G. barbadense* L. var. *brasiliensis* in La Convención, Cusco, Perú provides new information on key characteristics for agronomy and textiles. Focusing on this specific cultivar, the study details its profile and relevance to the textile industry, highlighting its potential in textile selection and use. The results will enrich the knowledge base for future research and will also guide industry and farmers in strategic decisions about the conservation, cultivation, and processing of quality cotton from Amazonian regions.

Having access to reliable and recent data on cotton fiber quality allows farmers in the region's growing areas to select proper cultivars. This choice must be made considering the demands and specifications of local and international fiber trade (Yang, 2019; MINAM, 2020). Furthermore, understanding which cotton species produce the best quality fibers allows farmers to improve their yield and profitability in commercial growing areas (Li et al., 2014; Cotton Incorporated, 2018).

Research with samples of *G. barbadense* L. var. *brasiliensis* collected in the native community of Shivankoreni in the Megantoni district reveals important findings that can improve knowledge and will allow the development of new technologies for better use of cotton adapted to Amazonian regions, benefiting local farmers by valuing the productivity and strength of their crops adapted to unfavorable conditions. This study highlights the value of native cotton for strengthening the relationship between artisanal producers and the textile industry, ensuring a supply of quality fiber. In addition, this study highlights the importance of helping rescue traditional Peruvian products, promoting access to specialized markets and improving the quality of life of farmers.

Conclusion

This study highlights the vital importance of protecting the genetic diversity of *G. barbadense* L. var. *brasiliensis* through the exceptional fiber quality, highlighting its valuable contribution to the textile industry. The results reveal the urgency of adopting conservation measures and plant genetic improvement strategies that explore the wide variability of these native cotton accessions, charting a promising path for future research and the adoption of sustainable agricultural practices. The identification of exceptional genotypes represents new possibilities for the development of cotton cultivars with superior quality characteristics, increasing sustainability and improving the competitiveness of the Peruvian Amazonian in textile industry worldwide. Our results also indicate the importance of preserving the genetic variability of cotton accessions native to the Peruvian Amazon in a Gene Bank, since this information can serve as a basis for new studies on the genetic improvement of the crop.

Abbreviations

LEN	Staple length
MIC	Micronaire
STR	Fiber strength
ELO	Fiber elongation
SHO	Short fiber index
UNI	Length uniformity index
MAT	Maturity index

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Authors' contributions

Conceptualization: Morales-Aranibar L, Rivera MYN, Aguilera JG, and Steiner F; Data curation: Morales-Aranibar L, Morales-Aranibar CG, Aguilera JG, and Steiner F; Formal analysis: Morales-Aranibar L, Sáenz MC, Rivera MYN, Aguilera JG, and Steiner F; Funding acquisition: Morales-Aranibar L and Sáenz MC; Investigation: Morales-Aranibar L, Sáenz MC, Morales-Aranibar CG, Rivera MYN, Aguilera JG, Steiner F, Bardiviesso DM, and Zuffo AM; Methodology: Morales-Aranibar L, Sáenz MC, Morales-Aranibar CG, Rivera MYN, Aguilera JG, and Steiner F; Project administration: Morales-Aranibar L, Sáenz MC, and Morales-Aranibar CG; Resources: Morales-Aranibar L, Sáenz MC; Software: Morales-Aranibar L and Morales-Aranibar CG; Supervision: Morales-Aranibar L and Morales-Aranibar CG; Validation: Morales-Aranibar L, Sáenz MC, Morales-Aranibar CG, Rivera MYN, Aguilera JG, Bardiviesso DM, and Zuffo AM; Visualization: Morales-Aranibar L, Sáenz MC, Rivera MYN, Aguilera JG, Steiner F, Bardiviesso DM, and Zuffo AM; Writing – original draft: Morales-Aranibar L, Sáenz MC, Morales-Aranibar CG, Rivera MYN, Aguilera JG, Steiner F, Bardiviesso DM, and Zuffo AM; Writing – review & editing: Morales-Aranibar L, Sáenz MC, Morales-Aranibar CG, Rivera MYN, Aguilera JG, Steiner F, Bardiviesso DM, and Zuffo AM.

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Availability of data and materials

All the data relevant to the present study are included in the article. Any further details related to the experiments conducted can be made available by requesting the corresponding author.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no conflict of interest.

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