Plant physiology

Short article

Characterization of fruit, seed and fiber of *Gossypium raimondii* Ulbrich, a wild cotton ecotype

Caracterización del fruto, semilla y fibra de *Gossypium raimondii* Ulbrich, ecotipo algodón silvestre

Segundo Eloy López Medina,[1] José Mostacero León,[2] Carlos Helí Quijano Jara,[3] Armando Efraín Gil Rivero,[4*] María Fernanda Rabanal Che Leon[5]

[1] Researcher, Consejo Nacional de Ciencia, Tecnología e Innovación Tecnológica (Concytec). Trujillo, Peru. Email: slopezm@unitru.edu.pe. Orcid: https://orcid.org/0000-0001-7719-8607
[2] Researcher, Consejo Nacional de Ciencia, Tecnología e Innovación Tecnológica (Concytec). Trujillo, Peru. Email: jobryl990@yahoo.com. Orcid: https://orcid.org/0000-0003-2556-3013
[3] Lecturer, Universidad Nacional de Trujillo, Facultad de Ciencias Biológicas, Departamento de Ciencias Biológicas. Trujillo, Peru. Email: cquijano@unitru.edu.pe. Orcid: https://orcid.org/0000-0001-9269-9864
[4] Lecturer, Universidad Nacional de Trujillo, Facultad de Ciencias Biológicas, Departamento de Ciencias Biológicas. Trujillo, Peru. Email: a.gr108@hotmail.com. Orcid: https://orcid.org/0000-0002-4521-5588
[5] Master´s Degree student, Universidad Nacional de Trujillo, Escuela de Posgrado. Trujillo, Peru. Email: maferachel@gmail.com Orcid: https://orcid.org/0000-0002-1866-7714

Subject editor: Rafael Reyes Cuesta (Corporación Colombiana de Investigación Agropecuaria [AGROSAVIA])

Date of receipt: 03/12/2018
Date of approval: 22/08/2019

How to cite this article: López Medina, S. E., Mostacero León, J., Quijano, C. H., Gil Rivero, A. E., & Rabanal Che León, M. F. (2020). Characterization of fruit, seed and fiber of *Gossypium raimondii* Ulbrich, a wild cotton ecotype. *Ciencia y Tecnología Agropecuaria*, *21*(1), e1219

DOI: https://doi.org/10.21930/rcta.vol21_num1_art:1219

* Universidad Nacional de Trujillo. Avenida Juan Pablo II, Trujillo 13011, Peru

Abstract

In Peru, there are two endemic cotton species, namely *G. barbadense* L. and *G. raimondii* Ulbrich, which have been used since pre-Inca cultures. Currently, in Peru, the reevaluation and rescue of these species and their ecotypes are being carried out given a higher market demand, which seeks to avoid the use of artificial dyes. The current study was carried out, aiming at contributing to the characterization of the fruit, seed, and fiber of an ecotype of *G. raimondii* known as "wild cotton." Plant material from the district of San Benito, province of Contumazá, and department of Cajamarca was used. The experimental phase was carried out in the Laboratory of Genetics and Molecular Biology of Universidad Nacional de Trujillo, consisting of length and width measurements of cotton fruits, seeds, and fiber, as well as the number of locules and seeds per fruit. A statistical analysis of the descriptive type with 60 repetitions was considered for each component. The fruit had an average length of 2.14 cm and a width of 1.46 cm, with four locules. Seeds had an average length of 5.74 mm and a width of 3.25 mm, with an average of 23.6 seeds per fruit. On average, the fiber was 11.95 mm long and 7.34 µm wide. The characterization of the fruit, seed, and fiber of the "wild cotton" ecotype (*G. raimondii*) allows differentiating it from the "brown cotton" (*G. barbadense*) and the "green cotton" ecotype (*G. raimondii*). We recommend carrying out molecular studies that will help clarify the degree of relatedness of these species and ecotypes.

Keywords: cotton, cotton boll, *Gossypium raimondii*, textile industry, varieties

Resumen

En el Perú hay dos especies endémicas de algodón, *Gossypium barbadense* L. y *G. raimondii* Ulbrich, que han sido utilizadas desde las culturas preincas. Actualmente, en el Perú se busca reevaluar y rescatar estas especies en vista de una mayor demanda del mercado, que busca evitar el uso de colorantes artificiales. El presente estudio se llevó a cabo con el propósito de contribuir al conocimiento de la caracterización del fruto, semilla y fibra de un ecotipo de *G. raimondii*, conocido como "algodón silvestre". Para ello, se utilizó material vegetal del Distrito de San Benito, Provincia de Contumazá, Departamento de Cajamarca. La fase experimental se llevó a cabo en el Laboratorio de Genética y Biología Molecular de la Universidad Nacional de Trujillo, que consistió en las mediciones de la longitud y del ancho de frutos, semillas y fibras, así como el número de lóculos y semillas. Se consideró un análisis estadístico del tipo descriptivo con 60 repeticiones por cada componente. El fruto tuvo una longitud promedio de 2,14 cm y 1,46 cm de ancho, con cuatro lóculos. Las semillas tuvieron una longitud promedio de 5,74 mm y un ancho de 3,25 mm, con un promedio de 23,6 semillas por fruto. En promedio, la fibra tuvo 11,95 mm de largo y 7,34 µm de ancho. La caracterización del fruto, la semilla y la fibra del algodón silvestre, *G. raimondii*, permite diferenciarlo del algodón pardo, *G. barbadense*, y del ecotipo algodón verde (*G. raimondii*). Se recomienda continuar con estudios moleculares que permitan dilucidar el grado de emparentamiento de estas especies y ecotipos.

Palabras clave: algodón, bellota, *Gossypium raimondii*, industria textil, variedades

Introduction

Cotton belongs to the Malvaceae family (Matarrita, 1989). The genus *Gossypium*, with approximately 20 species, is distributed in tropical and subtropical regions of both hemispheres. In Peru, the presence of *Gossypium barbadense* L. is reported and is commonly known as "brown cotton," also finding two ecotypes of *G. raimondii* Ulbrich. The first is known as "green cotton," and the second, as "wild cotton" that thrives in natural environments; it is probably the ancestor of the native and commercial varieties of cotton in Peru (Brako & Zarucchi, 1993). According to Mostacero, Mejía and Gamarra (2009), wild cotton is endemic in the departments of Cajamarca and La Libertad, where today, cotton relics survive in surrounding areas where no human beings have established.

Morphologically, the cotton plant is relatively simple, and its phenology varies according to the species and the influence of the environment (López & Gil, 2017; Matarrita, 1989). The ecotype known as wild cotton is the species *G. raimondii*, characterized as being a perennial, erect or prostrate and tree-like plant, which can reach a height of up to 4 m (Fernández & Rodríguez, 2007). It is found in rocky, stony terrain, riverbeds, and irrigation ditches, at an altitude of 1,600 m a.s.l. (Mostacero et al., 2009).

The ancient Peruvians on the north coast of Peru domesticated and cultivated native cotton with brown, green, and lilac fiber to elaborate their fabrics (Fernández, Rodríguez, & Westengen, 2003). Archaeological studies by Stephens and Moseley (1975) have demonstrated the domestication process of wild to native cotton, with the report of seeds that represent an intermediate form between wild and native cotton in Huaca Prieta. It is assumed that the center of origin and diversity of native colored cotton is the northern part of Peru, where brown cotton (*G. barbadense*) and green cotton (*G. raimondii*) are closely related geographically, ecologically and genetically to the wild cotton ecotype (*G. raimondii*) (Fernández & Rodríguez, 2007).

The cotton fruit is a capsule whose shape can be elongated, ovoid or spherical. The capsule takes approximately 50 days to mature, grows rapidly and reaches its normal size three weeks after fertilization. Its size varies according to the species, variety, and environmental conditions (Fernández & Rodríguez, 2007). The fruits are characterized by the union of their carpels to a central axis, which originates a series of locules, which contain the seeds (Robles, 2012); premature fruit fall is normal in the cotton plant and is increased by factors such as soil moisture, nutrient deficiency and temperature conditions (Matarrita, 1989).

The seeds are usually ovoid, slightly angular, and with a fissure in the margin (Fernández, Rodríguez, & Westengen, 2003). The seed consists of a testa, two large cotyledons, and a small embryo, containing between 15 % to 20 % protein, and up to 21 % oil (Fernández & Rodríguez, 2007).

The fibers or hairs are formed from the constant lengthening of the epidermal cells of the seed, and the thickening results from the continuous deposition of cellulose in the primary fiber wall (Fernández & Rodríguez, 2007; Fernández et al., 2003). Epidermal cells give rise to the formation of two different types of fiber: the first, long and thin, of 1.5 to 6.0 cm in length, with a thickness between 20 and 30 microns, can be woven or spun; the second, shorter and attached to the seed, constitutes the linter (Matarrita, 1989).

For many years, the cultivation of colored fiber cotton was abandoned for improved varieties of white fiber, due to their precocity, production and lower incidence of pest insects (Gil & López, 2017; Kwiatkowska & López, 2000); however, on the other hand, these fiber colored varieties have higher adaptability and drought resistance (Fernández et al., 2003).

Nonetheless, this resulted in the loss of germplasm of many diverse and natural pigmented cotton varieties, which were used by thousand-year-old

cultures in ancient Peru (Kwiatkowska & López, 2000). However, the situation has changed since 2008, with Regulation No. 29224, which states color fiber cotton as a genetic, ethnic, and cultural heritage (Pisani, Masiero, & Scrocco, 2015). Currently, research has shown that color fiber is a genetically inherited trait, which results from the presence of pigments intermingled with cellulose, being controlled by partial dominance genes (Bhuyan & Saikia, 2005; De Carvalho, Correia, De Andrade, & Da Silva, 2014; Wang et al., 2014).

At present, there is an interest in rescuing these varieties in response to the demand of the modern textile industry that seeks cleaner technologies, avoiding the use of carcinogenic dyes derived from petroleum. Thus, in the near future, these varieties of colored fiber may replace those of white cotton (Kwiatkowska & López, 2000), due to their natural color and the valuation of their fibers in international markets (Pisani et al., 2015). Although little is known about these varieties, there are communities in the departments of Lambayeque, Piura and San Martín that retain ancestral knowledge about the cultivation and processing of these varieties, from which they obtain thick yarns suitable for making bags, ornaments, clothing and other accessories (Cortijo & Cancio, 2012).

Studies of fruit, seed and fiber characterization in cotton are of great importance, because they provide information on the genotype of a given species, to obtain recombinants with better characteristics (Méndez & Alcorcés, 2007), as well as information that corroborates the denomination of wild cotton and the ecotype under study. Given the need for greater knowledge, the aim of this study was to characterize the fruits, seeds, and fibers of the *G. raimondii* ecotype called wild cotton.

Materials and methods

Botanical material collection

The collections were made in three areas located in the sectors called Quebrada de Los Molles and Puente de la Primera Agua (low and high zone) of the district of San Benito, province of Contumazá, department of Cajamarca, Peru (figure 1). The coordinates of San Benito are 07°25'32" S and 78°55'37" W, at an altitude of 1,370 m a.s.l. In these locations, wild cotton relics were identified based on the botanical explorations described by Brako and Zarucchi (1993) and Mostacero et al. (2017). Fifteen plants from each relict zone were randomly selected, of which 60 ripe fruits were collected per zone, comprising a total of 180 fruits. Besides, floriferous branches of wild cotton (*G. raimondii*) were collected for taxonomic identification and were registered in the Truxillense Herbarium (HUT) with code 59196.

Study area

The study was carried out in the Laboratory of Genetics and Molecular Biology of Universidad Nacional de Trujillo, located in the city of Trujillo, department of La Libertad, Peru (figure 1).

Measurement variables

Fruit and seed characteristics

The length and width of the fruits (cm) and seeds (mm) were measured using a precision gauge (vernier, Truper, U.S.), with a measuring scale between 0 and 150 mm. The number of seeds and locules per fruit was counted.

Fiber characteristics

The fiber length (mm) was measured with an Olympus SZX16 stereoscope. The equipment had a resolution of 900 pairs of lines/mm and a measuring scale of 3.5x to 230x. An Olympus BX41 microscope equipped with a DP72 camera was used to measure the fiber width (µm). The equipment had a resolution of 3.36-0.27 µm and a measurement scale between 40x and 1,000x.

Figure 1. Location of the departments of La Libertad and Cajamarca, Peru.
Source: Elaborated by the authors

Data analysis

A descriptive statistical analysis was considered, consisting of a sample of 180 ripe fruits, of which 60 fruits were randomly selected, comprising the number of repetitions per component evaluated. For this, the average, the deviation, and the standard error were estimated using the statistical program R.

Results and discussion

Fruit and seed characteristics

Comparing the wild cotton ecotype (*G. raimondii*) and the brown cotton (*G. barbadense*), the first shows small fruits of 2.14 ± 0.18 cm long and 1.46 ± 0.11 cm wide (table 1), as well as very small seeds that measure 5.74 ± 0.45 mm long and

3.25 ± 0.33 mm wide; on the other hand, the fruits of the second, have an average length of 4.264 cm and a width of 4.107 cm. Moreover, the seeds have an average of 0.784 cm long and 0.488 cm wide (López, López, Gil, Caicedo, & Mendoza, 2018).

Nonetheless, wild cotton has a higher number of locules and seeds (23.6 ± 2.61) in comparison to the brown cotton, in which an average of 4 lobes and between 20 and 21 seeds per fruit are reported (Gil & López, 2015). It is important to consider that Matarrita (1989) reported that native and wild cotton could have between 4 and 5 lobes versus the commercial cotton that has up to 3 lobes per fruit. It is also essential to highlight the presence of green linters in the seed of the common ecotype (*G. raimondii*), which is not evident in the brown cotton (*G. barbadense*) (Gil & López, 2015).

Another study considers that wild plants or with incipient domestication are those that show defense structures such as hairs in the seeds (linters) and small fruit and seed sizes, which are evidenced in wild cotton (*G. raimondii*) (Medina, 2011). On the other hand, brown cotton (*G. barbadense*) shows characteristics associated with domesticated crops (Gil & López, 2015), given that domestication syndrome is associated with dramatic alterations in plant morphology, with evidence of an increase in the weight and size of fruits and seeds (Medina, 2011).

Table 1. Summary of the characteristics of the fruit, seed, and fiber of the wild cotton ecotype (*G. raimondii*)

Characteristics	N	Average ± Standard deviation	Standard error
Fruit length (cm)	60	2.14 ± 0.18	0.0229
Fruit width (cm)	60	1.46 ± 0.11	0.0145
Number of locules	60	4.0 ± 0.0	0
Fiber width (μm)	60	7.34 ± 2.39	0.309
Fiber length (mm)	60	11.95 ± 1.53	0.198
Seed length (mm)	60	5.74 ± 0.45	0.058
Seed width (mm)	60	3.25 ± 0.33	0.0429
Number of seeds per boll	60	23.6 ± 2.61	0.337

Source: Elaborated by the authors

Figure 2. Length and width measurement of the fiber of the wild cotton ecotype (*G. raimondii*).

Fiber characteristics

Concerning fiber (tablmm and a width of 7.34 ± 2.39 µm, much smaller than brown cotton and the green cotton ecotype. Brown cotton (*G. barbadense*) shows an average length of 13.061 mm and a width of 24.245 µm (López et al., 2018), while the green cotton ecotype (*G. raimondii*) shows an average length of 25.835 mm and a width of 12.639 µm (López, Gil, & López, 2017).

Nonetheless, the main limitations of these cotton varieties for industrialization purposes are factors as the width and length of the fiber (Fernández et al., 2013), considering that Matarrita (1989) cataloged the native and wild cotton as short fiber varieties versus commercial long-fiber hybrid cotton. However, it is important to consider that the hybrid species developed by the cross between a commercial and a wild variety show a higher fiber quality and quantity in terms of resistance and elongation (Fernández et al., 2013).

On the other hand, it is crucial to keep in mind that fertilization with NPK improves the characteristics of the cotton boll (seeds and fibers), being able to increase the resistance of its fibers and its micronaire (Méndez, 2007; Palomo, Gaytán, Faz, Reta, & Gutiérrez, 2014; Staut & Athayde, 1999).

Conclusions

The characterization of the fruit, seed, and fiber of the wild cotton ecotype (*G. raimondii*) allows differentiating it from the brown cotton (*G. barbadense*) and the common green cotton ecotype (*G. raimondii*). We recommend continuing with molecular studies that allow elucidating the degree of relatedness of these species and ecotypes.

Acknowledgments

The authors wish to acknowledge the Laboratory of Genetics and Molecular Biology of Universidad Nacional de Trujillo, Peru, for providing us access to their modern facilities to carry out this research.

Disclaimers

The authors agree with the publication of this article and declare that there are no conflicts of interest that affect the results of this study.

References

Bhuyan, R., & Saikia, C. (2005). Genetic mapping of fiber color genes on two brown cotton cultivars in Xinjiang. *Bioresource Technology*, *96*(3), 363-72. doi:10.1186/2193-1801-3-480.

Brako, L., & Zarucchi, J. (1993). *Catálogo de las angiospermas y gimnospermas del Perú*. (Vol. 46). Missouri, EE. UU.: Monographs in Systematic Botany from the Missouri Botanical Garden.

Cortijo, D., & Cancio, R. (2012). Innovación tecnológica para recuperar el algodón nativo de color. *Ingeniería Industrial*, *30*(1), 225-245.

De Carvalho, L., Correia, F., De Andrade, M., & Da Silva, J. (2014). Inheritance of different fiber colors in cotton (*Gossypium barbadense* L.). *Crop Breeding and Applied Biotechnology*, *14*, 256-260. doi:10.1590/1984-7033 2014v14n4n40.

Fernández, A., & Rodríguez, E. (2007). *Etnobotánica del Perú pre- hispano*. Trujillo, Perú: Herbarium Truxillense (HUT). Retrieved from https://static1.squares pace.com/static/54b98e1ee4b0b6572f801af7/t/5579e0dfe-4b00046e7a025df/1434050783296/ETNOBOTANICA+DEL+PERU+PREHISPANO_Fern%C3%A1ndez+y+Rodriguez.pdf.

Fernández, A., Rodríguez, E., & Westengen, O. (2003). Biología y etnobotánica del algodón nativo peruano (*Gossypium barbadense* L., Malvaceae). *Arnaldoa*, *10*(2), 92-107.

Gil, A., & López, S. (2015). Germination characteristics of native cotton, *Gossypium* sp., seeds of green, lilac and brown. *Rebiol*, *35*(2), 39-46.

Gil, A., & López, S. (2017). Principal plagues and beneficial insects of *Gossypium hirsutum* L. "Native Cotton" of green fiber in relation to its phenological cycle. *Arnaldoa*, *24*(1), 359-368. doi:10.22497/arnaldoa.241.24118.

Kwiatkowska, T., & López, R. (2000). *Ingeniería genética y ambiental: problemas filosóficos y sociales de la biotecnología*. Ciudad de México, México: Plaza y Valdés.

López, S., & Gil A. (2017). Phenology of *Gossypium raimondii* Ulbrich "native cotton" of green fiber. *Scientia Agropecuaria*, *8*(3), 267-271. doi:10.17268/sci.agropecu. 2017.03.09.

López, A., López, S., Gil, E., Caicedo, & E., Mendoza, E. (2018). Caracterización de frutos, semillas y fibras de *Gossypium barbadense* "algodón Pardo". *Sciendo*, *21*(3), 301-304.

López, S., Gil, E., & López, A. (2017). Caracterización de fibras y características germinativas de semillas de *Gossypium raimondii* Ulbrich "algodón nativo" de fibra de color verde como base para su conservación e incorporación a la industria textil. En W. E. Reyes Avalos (Ed.), *Libro de resúmenes del VIII Congreso Nacional de Estudiantes de Biología* (p. 56). Nuevo Chimbote, Perú: Universidad Nacional de Santa.

Matarrita, A. (1989). *Cultivo de algodón*. San José, Costa Rica: Universidad Estatal a Distancia.

Méndez, J., & Alcorcés, N. (2007). Boll, seed and fiber traits of eight cotton cultivars under savanna conditions. *Revista de la Facultad de Agronomía (LUZ)*, *24*(1), 285-293.

Méndez, J. (2007). Effect of plant stand and fertilization on fruit traits in cotton (*Gossypium hirsutum* L.). *IDESIA*, *24*(3), 39-47.

Medina, C. (2010). *Domesticación de las plantas cultivadas*. Trujillo, Perú: Graficart.

Mostacero, J., Mejía, F., & Gamarra, T. (2009). *Fanerogamas del Perú. Taxonomía, utilidad y ecogeografía*. Trujillo, Perú: Concytec.

Mostacero, J., Lopéz, E., Yabar, H., De La Cruz, J. (2017). Preserving traditional botanical knowledge: The importance of phytogeographic and ethnobotanical inventory of Peruvian dye plants. *Plants*, *6*(4), 63-77.

Palomo, A., Gaytán, A., Faz, R., Reta, D., & Gutiérrez, E. (2004). Cotton yield and fiber quality in response to nitrogen rate and number of irrigations. *Terra Latinoamericana*, *22*(3), 299-305.

Pisani, E., Masiero, M., & Scrocco, S. (2015). Reintroduction of native cotton (*Gossypium barbadian*) on the North coast of Peru: Analysis of economic feasibility for small producers. *Revista de la Facultad de Ciencias Agrarias*, *47*(1), 209-232.

Robles, R. (2012). *Producción de oleaginosas y textiles*. Ciudad de México, México: Limusa.

Staud, L., & Athayde, M. (1999). Efeitos do fósforo e potássio no rendimento e em outras características agronômicas do algodoeiro herbáceo. *Pesquisa Agropecuária Brasileira*, *34*(10), 1839-1843. doi:10.1590/S0100-204X1999 0010000 10.

Stephens, S., & Moseley, M. (1974). Cotton remains from archeological sites in central coastal Peru. *Science*, *180*(4082), 186-188. doi:10.1126/science.180.4082.186.

Wang, L., Liu, H., Li, X., Xiao, X., Ai, X., ... Li, X. (2014). Genetic mapping of fiber color genes on two brown cotton cultivars in Xinjiang. *Springer Plus*, *3*, 480-485. doi:10. 1186/2193-1801-3-480.