

REGISTRATION

Cultivar

Registration of 'CA 4019' cotton cultivar

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Assigned to Associate Editor Jodi Scheffler.

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Funding information

0-CSREES Hatch Project; Plains Cotton Growers / Plains Cotton Improvement Program

Abstract

Upland cotton (*Gossypium hirsutum* L.) production is a staple for the economy of the Texas High Plains. The area is responsible for a large portion of the U.S. cotton production. Local water resources are being depleted, forcing producers to maximize production quality and quantity with restricted or minimal irrigation resources. Providing genetic resources suitable to meet the standards of West Texas cotton has been a long-established goal of the Texas A&M AgriLife cotton breeding program at Lubbock, TX. Cultivar 'CA 4019' (Reg. No. CV-150; PI 709332) cotton, resulted from a cross between 'MD26ne' (PI 666042) and an unreleased breeding line, '11-14-1208', from the cotton breeding program at Texas A&M AgriLife Research and Extension Center at Lubbock. CA 4019 has displayed superior yield capabilities in water-limited environments, along with a high-quality fiber package. Fiber quality measurements of micronaire and length uniformity were significantly improved compared with those of the commercial checks included in the trials. Improvements were also seen in fiber strength, elongation, and length. This cultivar offers a resource for improved fiber quality combined with improved yield potential under limited-water conditions and other environmental stressors of the Texas High Plains.

Plain Language Summary

Upland cotton (*Gossypium hirsutum* L.) production is a staple for the economy of the Texas High Plains. The area is responsible for a large portion of the U.S. cotton production. Local water resources are being depleted, forcing producers to maximize production quality and quantity with restricted or minimal irrigation resources. Providing genetic resources suitable to meet the standards of West Texas cotton has been a long-established goal of the Texas A&M AgriLife cotton breeding program at Lubbock, TX. Cultivar 'CA 4019' was developed by the Lubbock breeding program at the Texas A&M Research and Extension Center. CA 4019 has displayed superior yield capabilities in water-limited environments, along with a high-quality fiber package.

Abbreviations: CA, Cotton Accession; EPSM, El Paso Source Material; FBRI, Texas Tech University Fiber and Biopolymer Research Institute; HRC, Texas A&M Research Center in Halfway; HVI, High Volume Instrument; IPS, individual plant selection; LREC, Texas A&M AgriLife Research and Extension Center at Lubbock.

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This cultivar offers a resource for improved fiber quality combined with improved yield potential under limited-water conditions and other environmental stressors of the Texas High Plains.

1 | INTRODUCTION

Texas is a leader for upland cotton (*Gossypium hirsutum* L.) production. Approximately 1.6 million hectares of cotton are grown in the Texas High Plains Region annually, despite the region's decreasing water availability and harsh growing environments. Local producers are searching for cultivars capable of producing high yields with premier fiber qualities suitable for the area.

The region's long-term drought has reduced water availability, impacted irrigation rates, and increased the dependency on in-season rainfall for crop production. Farmers have adapted to the environmental challenges by adopting more conservative irrigation practices, focusing on maintaining soil moisture, and prioritizing cultivar selection. From 2013 to 2022, the percentage of cotton bales classed by the Lubbock, TX, USDA Cotton Classing Office ranged from 10.98% to 22.59% of the total U.S. bales (EFS-USCROP, 2000–2023). Despite the best efforts to minimize the drought's impact on each year's crop, yield is still largely dependent on the season's rainfall.

Almost 80% of a cotton crop's value is attributed to fiber production alone (Liu et al., 2015). In the Southern High Plains (which includes the Texas counties of Lubbock, Bailey, Lynn, Farmer, Castro, Swisher, Lamb, Hale, Floyd, Cochran, Hockley, Crosby, Yoakum, Terry, Garza, Gaines, Dawson, and Borden), the average dryland crop produced 382 kg ha⁻¹ in 2018. The average production for an irrigated crop was 915 kg ha⁻¹ in the same year (USDA, 2023).

Fiber quality also impacts the economic return of a cotton crop. The textile industry relies on the efficient, mass production of high-quality fiber, whether naturally or synthetically produced. As the quality of fiber deteriorates, spinnability and dyability of yarn follow, reducing the caliber of textile that can be produced (Kelly et al., 2015). Naturally produced fibers are a product of the genotype in its environment. Because of this interaction, the traits of a natural fiber can reduce or increase the marketability of a crop. The challenge for cotton farmers is to compete with the production speed and consistency of high-quality synthetic fibers, despite the variability introduced by the growing environment and genetics (Kelly et al., 2015). Variation in fiber quality can result from developmental disruptions due to environmental stressors and changes, especially in the Southern Great Plains. For example, the intensity of heat can impact fiber maturity, as shown by Pettigrew (2008). Water availability and drought stress frequently

prevent the development of high-quality lint (Lascano et al., 2017).

According to data collected by the USDA Cotton Classing Office, the average fiber quality of the bales classed at the Lubbock location has fluctuated throughout the last decade, and mean fiber micronaire (a unitless measurement of fiber maturity and fineness) ranged from 3.21 to 4.34 (EFS-USCROP, 2000–2023). Average cotton fiber strength data from the past decade have ranged from 29.5 to 31.1 g tex⁻¹ at the Lubbock Classing office, and these values also appear to be dependent on the availability of environmental resources (EFS-USCROP, 2000–2023).

The cotton breeding program at the Texas A&M AgriLife Research and Extension Center at Lubbock (LREC) developed 'CA 4019' as a result of this breeding objective. Cultivar CA 4019 (Reg. No. CV-150; PI 709332) cotton contributes exemplary cotton lint turnout and fiber quality, both necessary characteristics and crucial for Texas High Plains cotton production.

2 | MATERIALS AND METHODS

2.1 | Early-Generation Population and Line Development

CA 4019 was developed from a 2013 cross between 'MD26ne' (PI 666042) and a previously unreleased breeding line, '11-14-1208', from the LREC breeding program. MD26ne is a germplasm release from the USDA-ARS in Stoneville, MS (Meredith, 2013), released for its resistance to pests, along with its improved fiber quality and yield. The second parent, 11-14-1208, was derived from a complex cross involving 'CA 3240', an unofficially released breeding line, 'FM 989', and MD26ne. CA 3240 is a tall, prolific, tight-bolled, semi-smooth leaf, internal program germplasm developed using El Paso Source Material (EPSM). EPSM material has limited pedigree information due to its acquisition history. The EPSM designation was assigned to all material transferred from the El Paso, TX, breeding program in the early 1980s (Dever et al., 2021). The unreleased breeding line was selected as a parent for its yield potential. FiberMax FM 989 (PVP 009800259) is a commercial cultivar known to exhibit excellent fiber quality, and MD26ne was included for pest resistance with good fiber quality and yield potential.

The F₁ generation was grown during the winter of 2013–2014 and self-pollinated in Mexico at the National Cotton Council–sponsored winter nursery. The resulting F₂ seed was planted in an irrigated nursery at LREC in 2014 in eight rows that were 9 × 1 m, and the plants were thinned to one plant per 20 cm. Individual plant selections (IPSS) were harvested based on visual assessments of productivity, plant type, and boll type. IPSS were hand harvested, ginned, and submitted to fiber testing. Reselections were made based on fiber quality.

From 2015 through 2018, the F₃, F₄, F₅, and F₆ generations were planted under pressure of *Verticillium dahliae* Kleb. (*V. dahliae*; which causes Verticillium wilt disease) at the AgriLife Research Center in Halfway, TX (HRC). From the F₃ and F₄ generations, a random 50-boll sample was hand harvested and ginned. The remainder of the plot was bulk harvested by hand. In 2017, the F₅ generation was planted at the HRC under pressure of *V. dahliae*, and individual plants were selected based on their lack of visible symptoms of Verticillium wilt disease. Seed from the selected material was planted as progeny rows in 2018, and whole-row selections were made based on the phenotypic assessment of each row. Disease resistance was not confirmed in the 2018 selected progeny row designated 18-16-3507, which was subsequently designated CA 4019.

During the development of CA 4019, all seed cotton samples were ginned on a laboratory tabletop 10-saw gin stand (Dennis Manufacturing Company, Inc.) at LREC. Larger, whole-row selections were ginned on a research gin equipped with a stick machine, feeder extractor, and saw lint cleaner (modified research scale, not commercially available). All fiber samples were submitted for fiber testing using the Uster HVI 1000 (High Volume Instrument) at the Texas Tech Fiber and Biopolymer Research Institute (FBRI).

2.2 | Performance Trial Evaluations

CA 4019 was entered into yield trials in 2019 at seven locations, including both irrigated and dryland trials with multiple soil types. FiberMax FM 989, FiberMax ‘FM 958’ (PVP 200100208; PI 619096), and Deltapine ‘DP 491’ (PVP 2001001595; PI 618609) were included in all the performance tests as check cultivars. CA 4019 was tested in Lamesa (at the Agricultural Complex for Advanced Research and Extension Systems [AG-CARES]), TX, in Amarillo fine sandy loam under two levels of center pivot irrigation (base, 27.4 cm; low, 20.8 cm total irrigation); at Halfway, TX, in Olton loam under center pivot irrigation; in yield trials at the LREC with two trials that were furrow irrigated and one dryland trial, all on an Olton clay loam/Acuff loam. All trials took place between the years of 2019 and 2021 (Table 1). The field design for all performance tests was a randomized complete block design with four replications. Entries were arranged in two-row plots,

roughly 1 m wide and 7.6–10.6 m long, depending on the available acreage each year.

In-season, phenotypic visual assessments were made at each location prior to harvest. Researchers evaluated the overall appearance of each plot in every environment, as well as plant maturity (relative to the experimental checks), storm tolerance or boll type, and plant height. Other phenotypic data collected after harvest included lint yield, lint and seed gin turnout, boll weight, seed index, lint index, and seeds per boll.

Plots were subjected to a random 50-boll per plot sample. After boll sampling, each of the plots was mechanically harvested with a two-row John Deere (model 482) stripper modified for experimental plot harvest. The stripped cotton was combined with the boll samples to determine overall yield, as well as lint and seed gin turnout. Harvest and ginning protocols along with calculations have been previously described by Kelly et al. (2021).

All grab samples and boll samples were ginned at LREC on a 10-saw research gin equipped with a stick machine, feeder extractor, and saw lint cleaner. A fiber sample was taken from each grab sample and submitted to FBRI for HVI analysis. Performance test data were analyzed with Agrobases Generation II, version 38.24.2 (Agronomix Software, 2012), using the general linear model and genotype × environment model. Environments included Lamesa, TX, in 2019; LREC fields in 2020 and 2021; and Halfway, TX, in 2019 and 2021. Least significant difference was used for mean separation at the 0.05 probability level.

3 | CHARACTERISTICS

Environment was a significant to highly significant interaction for all characteristics (Table 2). Genotype had a significant impact on yield, lint and seed ratios, seed index, storm tolerance, plant maturity, and all fiber quality measurements except leaf trash content in the sample and yellowness. Genotype × environment was significant for seed and lint percentage turnout, storm tolerance, and uniformity measured by HVI. The main characteristics of interest, such as yield and commercially measured fiber properties, did not have a significant genotype × environment interaction.

CA 4019 had significantly higher yields and lint turnout than commercial checks Deltapine DP 491, FiberMax FM 989, and FiberMax FM 958 (Table 3). The mean yield of CA 4019 was 823 kg ha⁻¹, numerically greater than all checks and significantly better than FM 989 averaged across the seven test sites on the Texas High Plains. Storm tolerance of CA 4019 is 4.9, representing a semi-tight boll type, likely to display some tolerance to the wind and thunderstorms that can occur on the High Plains. Tighter boll types can decrease lint loss due to weather events, preventing yield reduction. CA 4019 had a visual maturity rating comparable to two of the

TABLE 1 Soil type, irrigation type, planting date, and harvesting date for ‘CA 4019’ from 2019 to 2021.

Year	Location	Soil type	Irrigation type	Estimated in-season irrigation (cm)	Estimated in-season rainfall (cm)	Plant date	Harvest date
2019	AG-CARES Lamesa, TX	Amarillo fine sandy loam	Pivot	19.6	13.0	May 16	Nov. 2
2019	AG-CARES Lamesa, TX	Amarillo fine sandy loam	Pivot	0.0	13.0	May 17	Nov. 2
2019	HRC Halfway, TX	Pullman clay loam	Pivot	20.1	47.0	May 14	Dec. 3
2020	LREC Lubbock, TX	Olton clay loam	In furrow	41.4	20.6	May 27	Nov. 11
2021	LREC Lubbock, TX	Olton clay loam	Dryland	0.0	45.0	June 8	Oct. 29
2021	LREC Lubbock, TX	Olton clay loam	In furrow	14.0	45.0	June 9	Dec. 2
2021	HRC Halfway, TX	Pullman clay loam	Pivot	21.1	47.5	June 20	Nov. 12

Abbreviations: AG-CARES, Agricultural Complex for Advanced Research and Extension Systems; HRC, AgriLife Research Center in Halfway, TX; LREC, Texas A&M AgriLife Research and Extension Center.

TABLE 2 ANOVA mean squares for ‘CA 4019’ and three commercial check characteristics across multiple environments.

Source	df ^a	Yield	Plant height	df ^a	Turnout		df ^b	Seed index	df ^a	Maturity	Storm tolerance ^c
					Seed	Lint					
Total	103			95			51		103		
Environment	6	770,840***	4799.5***	6	129.2 ***	26.8 ***	5	51.9***	6	4562.5***	14.6***
Genotype	3	129,765**	186.8	3	23.5	84.2***	3	2.1***	3	659.2**	5.9***
Gen × Env	18	17,179	143.3	18	9.2**	2.7***	15	0.1	18	104.6	0.7*
Error	57	9970	159.4	51	3.7	0.6	21	0.1	55	60.8	0.3
Source	df ^b	Micronaire	Length	Uniformity	Strength	Elongation	Leaf	Reflectance	Yellowness		
Total	59										
Environment	6	1.8***	11.7***	14.4***	2264.1***	0.5***	5.4**	41.5***	3.00***		
Genotype	3	0.2*	8.8***	10.0**	3069.6***	1.0***	3.1	5.6**	0.03		
Gen × Env	18	0.1	0.1	1.2*	304.2	0	1.2*	0.9	0.01*		
Error	23	0	0.3	0.5	168.8	0	0.6	0.6	0.01		

Note: Environments included Lamesa, TX, in 2019; LREC Fields in Lubbock, TX, in 2019 and 2021; and Halfway, TX, in 2020 and 2021.

Abbreviations: Gen × Env, genotype × environment interaction; LREC, Texas A&M AgriLife Research and Extension Center.

^aData is based on four replications.

^bData is based on two replications.

^cStorm tolerance is visually measured on a unitless scale of 1, being a loose and shatter-compliant boll, to 9, a tight and compact shatter-resistant boll.

*Significant at the .05 probability level. **Significant at the .01 probability level. ***Significant at the .001 probability level.

TABLE 3 Average phenotypic properties of ‘CA 4019’ and three commercial checks at multiple locations. Locations included Lamesa, TX, in 2019; LREC Fields in Lubbock, TX, in 2020 and 2021; and Halfway, TX, in 2019 and 2021.

Designation	Yield kg ha ⁻¹	Turnout		Boll weight	Seed index	Maturity	Storm tolerance ^a 1–9	Plant height cm
		Lint	Seed					
CA 4019	823a	28.2a	34.4b	5.3a	8.2c	53.4b	4.9b	56.2a
‘DP 491’	702b	24.3c	36.8a	5.2ab	9a	56.3b	4.2c	57.8a
‘FM 989’	691bc	24.4c	35.4ab	5.2ab	8.4bc	54b	4.7b	60.3a
‘FM 958’	663c	24.8bc	35.8ab	5b	8.8ab	64.7a	5.4a	53.9a
CV%	13.9	3.1	5.4	3.8	4.2	13.6	11.2	22.1

Note: Means followed by the same unsuperscripted letter are not significantly different from the other values in that column at the 0.05 probability level.

Abbreviation: LREC, Texas A&M AgriLife Research and Extension Center.

^aStorm tolerance is visually measured on a unitless scale of 1, being a loose and shatter-compliant boll, to 9, a tight and compact shatter-resistant boll.

TABLE 4 Fiber quality data of ‘CA 4019’ and three commercial checks across multiple environments. Environments included Lamesa, TX, in 2019; LREC Fields in Lubbock, TX, in 2020 and 2021; and Halfway, TX, in 2019 and 2021.

Designation	Micronaire	Length	Uniformity	Strength	Elongation	Leaf	Reflectance	Yellowness
		mm	%	kN m kg ⁻¹	%			
CA 4019	4.2a	28.6a	81.3a	313.8a	5.8a	2.3b	78.7a	8.6a
‘DP 491’	4.0b	28.2a	80.2b	307.2ab	5.9a	3.3a	77.8b	8.4ab
‘FM 989’	3.9b	27.3b	79.5c	295.3b	5.6b	2.9ab	78.7a	8.5ab
‘FM 958’	3.9b	26.9b	79.6bc	281.3bc	5.3c	2.5b	79.3a	8.22b
CV%	4.3	2.0	0.9	4.3	3.2	26.3	1.0	2.9

Note: Means followed by the same unsuperscripted letter are not significantly different from the other values in that column at the 0.05 probability level.

Abbreviation: LREC, Texas A&M AgriLife Research and Extension Center.

three checks across the tested environments. This indicates its growth habits should not negatively impact yield and fiber quality. This characteristic is important for cotton grown on the Texas High Plains, where the length of the growing season can vary significantly (Table 3).

CA 4019 presents an improved fiber quality package compared with the experimental controls. CA 4019 showed higher micronaire (4.2) and length uniformity (81.3%) than the three commercial checks (Table 4). CA 4019 displays a fiber length of 28.6 mm, which is longer than that of the commercial checks FiberMax FM 989 and FiberMax FM 958 but not different than DP 491 (Table 4). CA 4019 averaged greater fiber strength at 313 kN m kg⁻¹ than FiberMax FM 989 or FiberMax FM 958. Cotton fiber elongation, reflectance, and yellowness of CA 4019 were comparable to values of the commercial checks (Table 4).

4 | CONCLUSIONS

The Texas High Plains Region has long been a leading area for cotton production despite its harsh environment. CA 4019 has demonstrated high lint yield potential across multiple locations and production environments on the Texas High Plains, a desirable characteristic essential for continued commercial production. In comparison with the commercial checks, CA 4019 exhibited increased yield, lint percentage, and lint index, along with improved fiber qualities, consistent with high caliber textiles. Fiber properties such as micronaire and fiber length were improved in CA 4019 in comparison with the control cultivars. CA 4019 expands the portfolio of conventional cultivars available to producers and to private cotton breeders developing improved cultivars for the Texas High Plains.

5 | AVAILABILITY

Inquiries regarding potential commercial use should be directed to Texas A&M Innovation, MS 3369, College Station, TX 77843-3369, (979)-246-0500. Small quantities of

CA 4019, for research purposes, can be requested from C. M. Kelly, Texas A&M AgriLife Research, 1102 E. Drew St., Lubbock, TX 79403. Unless specifically approved by Texas A&M AgriLife Research, CA 4019 may not be used as a recurrent parent in a breeding program. Seed of CA 4019 has been deposited in the USDA-ARS National Plant Germplasm System, where it will be available for distribution 20 years after the date of publication.

AUTHOR CONTRIBUTIONS

Reagan B. Heinrich: Investigation; writing—original draft. **Carol M. Kelly:** Investigation; supervision; writing—review and editing. **Valerie A. Morgan:** Data curation; formal analysis; investigation. **Jane K. Dever:** Funding acquisition; methodology; project administration; supervision; writing—review and editing.

ACKNOWLEDGMENTS

CA 4019 was developed with support from the Plains Cotton Growers, Inc., Plains Cotton Improvement Program, and CSREES Hatch Project TEX 09297.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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How to cite this article: Heinrich, R. B., Kelly, C. M., Morgan, V. A., & Dever, J. K. (2025). Registration of ‘CA 4019’ cotton cultivar. *Journal of Plant Registrations*, 19, e70034. <https://doi.org/10.1002/plr2.70034>