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REGISTRATION

Germplasm

Registration of PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 germplasm lines of cotton

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Abstract

PD 20170048 (Reg. no. GP-1092, PI 698606), PD 20170049 (Reg. no. GP-1093, PI 698607), PD 20170050 (Reg. no. GP-1094, PI 698608), PD 20170053 (Reg. no GP-1095, PI 698609), and PD 20170054 (Reg. no. GP-1096, PI 698610) are noncommercial breeding lines of upland cotton (*Gossypium hirsutum* L.) jointly released by the USDA–ARS, the Clemson University Experiment Station, and Cotton Incorporated in 2020. PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 are breeding lines selected from a cross between an elite cultivar or germplasm line and an exotic landrace accession from Asia, Africa, or South America. Each breeding line possesses 50% exotic landrace parentage, excellent fiber quality, and excellent yield performance—significantly better than several commercial cultivars. PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 display good adaptation in three distinct regions of the U.S. upland cotton production region and provide valuable sources of new genetic diversity to cultivar development programs.

1 | INTRODUCTION

An infusion of genetic diversity is greatly needed to sustain future genetic improvement in upland cotton (*Gossypium hirsutum* L.). This diversity is necessary to support a global industry that accounts for nearly 35 million ha of production area and generates an annual farmgate value of US$35 billion (USDA Foreign Agricultural Service, 2020). Cotton genetic diversity estimates indicate an extremely narrow genetic base, with the average genetic distance between two genotypes being 0.145 (Tyagi et al., 2014) to 0.195 (Hinze et al., 2017). More recently, Chen et al. (2020) reported 1.7–5.2 single nucleotide polymorphisms kb^{-1} or 0.19–0.53% among five polyploid cotton genomes, which further substantiates the need for infusing new genetic diversity into mainstream cotton breeding.

To address the need for increased genetic diversity, we initiated a germplasm enhancement program to introgress genetic variation from exotic landrace accessions maintained by the USDA–ARS National Cotton Germplasm Collection in College Station, TX, into elite upland cotton genetic backgrounds. PD 20170048 (Reg. no. GP-1092, PI 698606), PD 20170049 (Reg. no. GP-1093, PI 698607), PD 20170050 (Reg. no. GP-1094, PI 698608), PD 20170053 (Reg. no GP-1095, PI 698609), and PD 20170054 (Reg. no. GP-1096, PI 698610) are noncommercial breeding lines of upland cotton containing 50% landrace parentage jointly released by the USDA–ARS, the Clemson University Experiment Station, and Cotton Incorporated. PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 were developed from a single cross derived from an elite upland germplasm line or cultivar and an exotic landrace accession collected from Asia, Africa, or South America (Table 1). These five breeding lines were released because they possess 50% exotic landrace parentage, excellent fiber quality, and excellent yield performance under a range of growing environments.

Core Ideas

- Upland cotton has an extremely narrow genetic base and needs an infusion of genetic diversity.
- These five germplasm lines each contain 50% landrace parentage.
- These five germplasm lines display good adaptation across three geographical regions of the United States.
- These five germplasm lines provide the cotton industry with critical new sources of genetic diversity.

2 | METHODS

PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 were developed using a modified shuttle breeding process involving the Coastal Plains Soil, Water, and Plant Research Center in Florence, SC, the Southern Plains Agricultural Research Center in College Station, TX, and the Arid-Land Agricultural Research Center in Maricopa, AZ. Each cross was made in the field at the Clemson University Pee Dee Research and Education Center in Florence, SC, in the summer of 2012 as part of a topcross test involving 13 day-neutral landrace accessions and six elite, upland germplasm lines and cultivars as described by Campbell et al. (2019). In the winter of 2012 and 2013, approximately 15 F_1 plants of each cross were self-pollinated at the USDA–ARS winter nursery in Tecoman, Mexico, and the F_2 seed bulked. Based on its yield performance in replicated field trials conducted at the Clemson University Pee Dee Research and Education Center in Florence, SC, and the Texas A&M AgriLife Research Farm near College Station, TX, in 2014, the F_2 bulk was advanced to the F_3 for single plant selection. In 2015, F_3 bulk populations were evaluated in non-replicated field plots in Florence. Individual F_3 plants were selected for day-neutral flowering, plant type, maturity, number of bolls, and fiber properties and advanced to $F_{3:4}$ progeny rows. In 2016, $F_{3:4}$ progeny rows were evaluated in augmented, single replicate repeating check trials conducted in either Florence and the University of Arizona Maricopa Agricultural Research Center in Maricopa, AZ, or in College Station and Maricopa. PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 were each derived from a single $F_{3:4}$ progeny row selected for plant type, fiber properties, and yield potential.

PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 were compared with three commercial check cultivars in one of two preliminary yield trials conducted in Florence, College Station, and Maricopa in 2017. Each of the preliminary yield trials contained 17 breeding lines and three commercial check cultivars with high yield potential, high fiber quality potential, or a combination of high yield and fiber quality: 'Deltapine 393' (PI 635100), 'Phytogen 72' (PI 617043), and 'UA 48' (PI 660508; Bourland & Jones, 2012). The first preliminary yield trial included PD 20170048 and PD 20170049 along with 15 additional breeding lines and the three commercial checks, while the second preliminary yield trial included PD 20170050, PD 20170053, and PD 20170054 along with 14 additional breeding lines and three commercial checks. In 2018 and 2019, PD 20170048, PD 20170049, PD 20170050, PD 20170053,

TABLE 1 Description of elite and landrace parents used to develop PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054

	Elite parent			Landrace parent			
Breeding line	Name	PI no.	Reference	Name	PI no.	Origin	Collection date
PD 20170048	PD 94042	603219	May (1999)	TX-1321	403928	Republic of Cote D'Ivoire	1975
PD 20170049	UA 48	660508	Bourland & Jones (2012)	TX-2318	607644	former Soviet Union	1987
PD 20170050	MD 25	659508	Meredith & Nokes (2011)	TX-2354	607669	Paraguay	1986
PD 20170053	UA 48	660508	Bourland & Jones (2012)	TX-2354	607669	Paraguay	1986
PD 20170054	UA 48	660508	Bourland & Jones (2012)	TX-1326	403933	Republic of Cote D'Ivoire	1975

and PD 20170054 were evaluated along with 12 additional breeding lines and the same three commercial check cultivars in an advanced yield trial conducted in Florence, College Station, and Maricopa.

Each trial was arranged in a randomized complete block design with three replications in 2017 and four replications in 2018 and 2019. Each entry was grown in a one-row plot, 10.7 by 96.5 cm, in 2017. In 2018 and 2019, at the Florence and College Station locations, each entry was grown in two-row plots 10.7 by 96.5 cm. Plots in Maricopa during 2018 and 2019 consisted of one row 10.7 by 96.5 cm. Plots were managed conventionally and followed the recommended local practices.

Each plot was harvested with a mechanical cotton picker modified for experimental plot harvest, and total seed cotton weight was recorded. For each trial, a 25- or 50-boll sample was obtained from each plot prior to harvest to determine lint percentage and fiber quality properties. Samples were ginned on a laboratory gin, and lint percentage was determined by dividing the weight of the lint sample after ginning by the weight of the lint sample before ginning. Lint yield was calculated by multiplying the lint percentage by the seed cotton yield. A portion of the lint sample was sent to the Cotton Incorporated Fiber Testing Laboratory (Cary, NC) for determination of micronaire, fiber length, uniformity index, fiber strength, elongation, and short fiber content by high-volume instrument (HVI) analyses. Two fiber quality indices or quality scores were calculated based on a weighted average of HVI fiber properties that included fiber length (50%), micronaire (25%), uniformity index (15%), and fiber strength (10%) for Quality Index 1 and fiber length (10%), micronaire (10%), uniformity index (30%), and fiber strength (50%) for Quality Index 2 (Bourland et al., 2010). In advanced yield trials conducted in 2018 and 2019, yield components were calculated and included boll size, seeds per boll, seed index (weight of 100 fuzzy seeds), and lint index (weight of lint per 100 seeds) as described by Campbell et al. (2016). Boll size was estimated by dividing the weight of the hand-harvested boll sample by 25 or 50, respectively. Seeds per boll was estimated by dividing the multiplication product of boll size and 100-lint percentage by the seed index.

Data from preliminary and advanced yield trials were analyzed for normality by PROC UNIVARIATE and an analysis of variance (ANOVA) was conducted in each of the two sets of trials within and across locations using PROC GLM with the RANDOM statement to test significant differences among genotypes (SAS Institute, 2002). Genotypes were considered fixed effects, while replications and locations were considered random effects. The least significant difference (LSD, P = .05) was calculated in each ANOVA to test specific differences between the check cultivars and PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054.

3 | CHARACTERISTICS

PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 display mid- to full-season maturity and combine excellent yield potential, fiber quality, and good adaptation. A summary of the agronomic and fiber quality performance from preliminary field trials conducted in Maricopa, Florence, and College Station during 2017 are provided in Table 2 (PD 20170048 and PD 20170049) and Table 3 (PD 20170050, PD 20170053, and PD 20170054). Agronomic and fiber quality performance from a single advanced field trial conducted in Maricopa, Florence, and College Station during 2018 and 2019 are summarized in Tables 4 and 5.

3.1 | PD 20170048

In 2017, PD 20170048 produced lint yield equal to Deltapine 393 and Phytogen 72 and greater than UA 48 (Table 2). Lint percentage was higher than Deltapine 393, Phytogen 72, and UA 48. Fiber length, micronaire, elongation, and Fiber Quality Index 2 were equal to Phytogen 72 and UA 48. PD 20170048 was equal to each check for fiber strength, uniformity, and short fiber content. For Fiber Quality Index 1, PD 20170048 was equal to Deltapine 393 and UA 48 and higher than Phytogen 72.

In an advanced yield trial conducted in Florence, College Station, and Maricopa in 2018 and 2019, PD 20170048 produced lint yield equal to Phytogen 72 and UA 48 and higher than Deltapine 393 (Table 4). Lint percentage of PD 20170048 was lower than the three check cultivars, while boll size, seeds per boll, and lint index were equal to the check cultivars. Seed index of PD 20170048 was higher than the check cultivars. PD 20170048 produced fiber length and strength equal to Deltapine 393 and Phytogen 72 and higher than UA 48 (Table 5). The micronaire of PD 20170048 was higher than Deltapine 393 but equal to Phytogen 72 and UA 48. PD 20170048 was equal to check cultivars for uniformity and Quality Index 1. For Quality Index 2, PD 20170048 was equal to Deltapine 393 and UA 48 and higher than Phytogen 72.

Overall, based on replicated trials in 2017–2019, PD 20170048 consistently performed equal or superior to commercial cultivars for lint yield, fiber length, fiber strength, uniformity, short fiber content, Quality Index 1, and Quality Index 2.

3.2 | PD 20170049

In 2017, PD 20170049 produced lint yield equal to Deltapine 393 and Phytogen 72 and greater than UA 48 (Table 2). Lint percentage was higher than Deltapine 393, Phytogen

TABLE 2 Mean agronomic and fiber quality performance of PD 20170048, PD 20170049, and check cultivars in field trials conducted in Florence, SC, College Station, TX, and Maricopa, AZ, in 2017

Line	Lint yield	Lint percentage	Fiber length	Fiber strength	Micronaire	Uniformity	Elongation	Short fiber content	Fiber quality index 1	Fiber quality index 2
	kg ha^{-1}	%	mm	kN m kg^{-1}		——%——				
Deltapine 393	951 bc	38.4 c	30.8 a	338 a	4.6 a	84.0 a	5.5 b	7.1 a	70 a	76 a
Phytogen 72	1,170 a	38.3 c	30.1 abc	327 a	4.8 ab	84.0 a	5.8 a	7.3 a	56 b	68 b
UA 48	897 c	38.6 c	29.8 c	332 a	4.9 b	83.8 a	5.9 a	7.3 a	60 ab	70 ab
PD 20170048	1,107 ab	39.5 b	30.0 bc	329 a	5.0 b	84.3 a	5.7 ab	7.2 a	70 a	69 ab
PD 20170049	1,054 ab	41.0 a	30.6 ab	329 a	4.9 b	83.8 a	5.7 ab	7.5 a	60 ab	70 ab

Note. Data extracted from larger, multiple-entry tests. Values in a column not followed by the same letter are significantly different ($P = .05$).

TABLE 3 Mean agronomic and fiber quality performance of PD 20170050, PD 20170053, PD 20170054, and check cultivars in field trials conducted in Florence, SC, College Station, TX, and Maricopa, AZ, in 2017

Line	Lint yield	Lint percentage	Fiber length	Fiber strength	Micronaire	Uniformity	Elongation	Short fiber content	Fiber quality index 1	Fiber quality index 2
	kg ha^{-1}	%	mm	kN m kg^{-1}		——%——				
Deltapine 393	1,048 cd	38.8 c	30.3 bc	338 ab	4.8 a	84.1 a	5.6 bc	7.6 a	65 a	72 ab
Phytogen 72	1,301 a	39.0 bc	29.8 c	329 b	4.9 ab	83.8 a	5.8 abc	7.3 a	63 ab	68 ab
UA 48	1,008 d	38.7 c	30.0 bc	330 b	5.0 bc	83.7 a	6.0 a	7.3 a	53 bc	67 ab
PD 20170050	1,263 ab	40.7 a	30.1 bc	329 b	5.1 c	83.7 a	6.0 a	7.6 a	48 c	66 b
PD 20170053	1,107 bcd	39.8 ab	31.1 a	346 a	5.1 c	83.8 a	5.9 ab	7.5 a	71 a	71 ab
PD 20170054	1,184 abc	39.8 ab	30.6 b	330 b	4.9 ab	84.4 a	5.7 bc	7.4 a	46 c	73 a

Note. Data extracted from larger, multiple-entry tests. Values in a column not followed by the same letter are significantly different ($P = .05$).

72, and UA 48. Fiber length and micronaire were equal to Phytogen 72 and UA 48. PD 20170049 was equal to each check for fiber strength, uniformity, elongation, short fiber content, Fiber Quality Index 1, and Fiber Quality Index 2.

In an advanced yield trial conducted in Florence, College Station, and Maricopa in 2018 and 2019, PD 20170049 produced lint yield equal to Phytogen 72 and UA 48 and higher than Deltapine 393 (Table 4). Lint percentage of PD 20170049 was lower than UA 48 but equal to Deltapine 393 and Phytogen 72. PD 20170049 was equivalent to check cultivars for boll size, seeds per boll, and seed index, while lint index was equal to Deltapine 393 and UA 48 but lower than Phytogen 72. PD 20170049 produced fiber length and Quality Index 1 superior to the check cultivars, while

TABLE 4 Mean agronomic performance of PD 20170048, PD 20170049, PD 20170050, PD 20170053, PD 20170054, and check cultivars in field trials conducted in Florence, SC, College Station, TX, and Maricopa, AZ, in 2018 and 2019

Line	Lint yield	Lint percentage	Boll size	Seed per boll	Seed index	Lint index
	kg ha^{-1}	%	g	no.	——g——	
Deltapine 393	1,266 b	40.6 c	5.0 a	29.9 a	9.8 bc	6.3 ab
Phytogen 72	1,646 a	41.3 ab	4.8 a	28.2 b	9.8 bc	6.5 a
UA 48	1,627 a	41.5 a	4.7 a	27.7 b	9.8 bc	6.4 ab
PD 20170048	1,631 a	39.8 d	5.0 a	28.9 ab	10.4 a	6.4 ab
PD 20170049	1,626 a	40.8 bc	4.7 a	28.6 ab	9.6 c	6.2 b
PD 20170050	1,694 a	41.3 ab	4.8 a	29.2 ab	9.6 c	6.3 ab
PD 20170053	1,666 a	40.8 bc	4.9 a	28.2 b	10.1 ab	6.5 ab
PD 20170054	1,625 a	40.4 c	4.9 a	28.9 ab	10.1 ab	6.3 ab

Note. Data extracted from larger, multiple-entry tests. Values in a column not followed by the same letter are significantly different ($P = .05$).

TABLE 5 Mean fiber quality performance of PD 20170048, PD 20170049, PD 20170050, PD 20170053, PD 20170054, and check cultivars in field trials conducted in Florence, SC, College Station, TX, and Maricopa, AZ, in 2018 and 2019

Line	Fiber length	Fiber strength	Micronaire	Uniformity	Elongation	Short fiber content	Fiber quality index 1	Fiber quality index 2
	mm	kN m kg^{-1}		———	%	———		
Deltapine 393	28.5 cd	314 ab	4.7 a	83.0 ab	6.5 de	7.6 bc	55 bcd	64 bcd
Phytogen 72	28.4 cd	312 ab	4.9 bc	82.5 b	6.9 a	7.9 a	52 cd	62 d
UA 48	28.3 d	310 b	4.9 bc	82.6 b	6.7 bc	7.7 ab	49 d	63 bcd
PD 20170048	28.8 bc	318 a	5.0 bcd	83.0 ab	6.6 cd	7.4 c	55 bcd	67 abc
PD 20170049	29.3 a	315 ab	4.8 ab	82.7 b	6.6 cd	7.9 a	63 a	67 abc
PD 20170050	29.1 ab	316 ab	5.0 bcd	83.3 a	6.7 c	7.6 bc	60 ab	69 a
PD 20170053	29.1 a	318 a	5.1 bcd	83.3 a	6.6 cd	7.5 bc	58 abc	68 ab
PD 20170054	29.4 a	317 ab	5.0 bcd	83.0 ab	6.4 e	7.6 bc	63 a	69 a

Note. Data extracted from larger, multiple-entry tests. Values in a column not followed by the same letter are significantly different ($P = .05$).

strength, micronaire, and uniformity were equal to the check cultivars (Table 5). For Quality Index 2, PD 20170049 was higher than Phytogen 72 and equal to Deltapine 393 and UA 48.

Overall, based on replicated trials in 2017–2019, PD 20170049 consistently performed equal or superior to commercial cultivars for lint yield, lint percentage, fiber strength, micronaire, uniformity, elongation, short fiber content, Quality Index 1, and Quality Index 2.

3.3 | PD 20170050

In 2017, PD 20170050 produced lint yield equal to Phytogen 72 and greater than Deltapine 393 and UA 48 (Table 3). Lint percentage was higher than Deltapine 393, Phytogen 72, and UA 48. PD 20170050 was equal to each check for fiber length, fiber strength, uniformity, short fiber content, and Fiber Quality Index 2. Micronaire was higher than Deltapine 393 and Phytogen 72 but equal to UA 48. Elongation was equal to Phytogen 72 and UA 48 and greater than Deltapine 393. For Fiber Quality Index 1, PD 20170050 was lower than Deltapine 393 and Phytogen 72 but equal to UA 48.

In an advanced yield trial conducted in Florence, College Station, and Maricopa in 2018 and 2019, PD 20170050 produced lint yield equal to Phytogen 72 and UA 48 and higher than Deltapine 393 (Table 4). Lint percentage of PD 20170050 was higher than Deltapine 393 and equal to Phytogen 72 and UA 48. PD 20170050 was equivalent to check cultivars for boll size, seeds per boll, seed index, and lint index. PD 20170050 produced fiber length and Quality Index 2 superior to check cultivars (Table 5). PD 20170050 produced strength equal to check cultivars, while micronaire was higher than Deltapine 393 and equal to Phytogen 72 and UA 48. Uniformity and Quality Index 1 of PD 20170050 was equal to Deltapine 393 and higher than Phytogen 72 and UA 48.

Overall, based on replicated trials in 2017–2019, PD 20170050 consistently performed equal or superior to commercial cultivars for lint yield, lint percentage, fiber length, fiber strength, micronaire, uniformity, elongation, short fiber content, and Quality Index 2.

3.4 | PD 20170053

In 2017, PD 20170053 produced lint yield lower than Phytogen 72 but equal to Deltapine 393 and UA 48 (Table 3). Lint percentage was equal to Phytogen 72 and higher than Deltapine 393 and UA 48. PD 20170053 was higher than all three checks for fiber length while equal to Deltapine 393 and greater than Phytogen 72 and UA 48 for fiber strength. Micronaire was higher than Deltapine 393 and Phytogen 72 and equal to UA 48. PD 20170053 was equal to all three checks for uniformity, elongation, short fiber content, and Fiber Quality Index 2. For Fiber Quality Index 1, PD 20170053 was equal to Deltapine 393 and Phytogen 72 and greater than UA 48.

In an advanced yield trial conducted in Florence, College Station, and Maricopa in 2018 and 2019, PD 20170053 produced lint yield equal to Phytogen 72 and UA 48 and higher than Deltapine 393 (Table 4). Lint percentage of PD 20170053 was lower than UA 48 but equal to Deltapine 393 and Phytogen 72. PD 20170053 was equivalent to check cultivars for boll size, seed index, and lint index. Seeds per boll was lower than Deltapine 393 but equal to Phytogen 72 and UA 48. PD 20170053 produced fiber length higher than the check cultivars, while strength was equal to Deltapine 393 and Phytogen 72 but higher than UA 48 (Table 5). PD 20170053 produced micronaire higher than Deltapine 393 and equal to

Phytogen 72 and UA 48. Uniformity of PD 20170053 was equal to Deltapine 393 and higher than Phytogen 72 and UA 48. PD 20170053 produced a Quality Index 1 greater than UA 48 and equal to Deltapine 393 and Phytogen 72, while Quality Index 2 was greater than Phytogen 72 and equal to Deltapine 393 and UA 48.

Overall, based on replicated trials in 2017–2019, PD 20170053 consistently performed equal or superior to commercial cultivars for lint yield, fiber length, fiber strength, uniformity, elongation, short fiber content, Quality Index 1, and Quality Index 2.

3.5 | PD 20170054

In 2017, PD 20170054 produced lint yield equal to Deltapine 393 and Phytogen 72 and greater than UA 48 (Table 3). Lint percentage was equal to Phytogen 72 but higher than Deltapine 393 and UA 48. PD 20170054 was equal to Deltapine 393 and UA 48 and higher than Phytogen 72 for fiber length. PD 20170054 was equal to the three checks for fiber strength, micronaire, uniformity, short fiber content, and Fiber Quality Index 2. Elongation was lower than UA 48 but equal to Deltapine 393 and Phytogen 72. For Fiber Quality Index 1, PD 20170054 was lower than Deltapine 393 and Phytogen 72 but equal to UA 48.

In an advanced yield trial conducted in Florence, College Station, and Maricopa in 2018 and 2019, PD 20170054 produced lint yield equal to Phytogen 72 and UA 48 and higher than Deltapine 393 (Table 4). Lint percentage of PD 20170054 was lower than Phytogen 72 and UA 48 but equal to Deltapine 393. PD 20170054 was equivalent to check cultivars for boll size, seeds per boll, seed index, and lint index. PD 20170054 produced fiber length, Quality Index 1, and Quality Index 2 superior to the check cultivars (Table 5). PD 20170054 produced strength equal to the check cultivars, while micronaire was higher than Deltapine 393 but equal to Phytogen 72 and UA 48. Uniformity of PD 20170054 was equal to the check cultivars.

Overall, based on replicated trials in 2017–2019, PD 20170054 consistently performed equal or superior to commercial cultivars for lint yield, fiber length, fiber strength, uniformity, short fiber content, and Quality Index 2.

4 | CONCLUSIONS

Overall, PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 represent genetic resources that provide 50% parentage from exotic landraces along with a combination of high lint yield and fiber quality potential. Based on field evaluations conducted in three distinct geographical regions of the U.S. Cotton Belt, PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 display good adaptation to the U.S. upland cotton production region that warrants their use in regions across the United States. In addition to their excellent agronomic and fiber quality performance, these germplasm lines provide the cotton industry with critical, new sources of genetic diversity.

5 | AVAILABILITY

Small quantities (20 g) of PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 seed may be obtained for breeding purposes from B. T. Campbell, USDA–ARS, Coastal Plains Soil, Water, and Plant Research Center, Florence, SC 29501, USA. Seed of PD 20170048, PD 20170049, PD 20170050, PD 20170053, and PD 20170054 has been deposited into the USDA-ARS National Laboratory for Genetic Resources, where it will be available immediately upon publication. It is requested that appropriate recognition of the source be given when these germplasm lines contribute to the development of a new breeding line, hybrid, or cultivar.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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