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Agronomic and technical fibers traits in elite genotypes of cotton herbaceous

Luiz Paulo de Carvalho[1], Francisco José Correia Farias[1], Camilo de Lellis Morello[1], Josiane Isabela da Silva Rodrigues[1] and Paulo Eduardo Teodoro[2]*

[1]National Center for Cotton Research (CNPA), Embrapa Algodão, 58107-720, Campina Grande, PB, Brasil.
[2]Department of Crop Science, Universidade Estadual de Mato Grosso do Sul, Unidade Universitária de Aquidauana (UEMS), Brazil.

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The changes in weaving technology, competition with synthetic fibers, and the globalization of cotton and textile production have increased the demand for better quality fibers. One of the main traits to be improved is fiber length. Thus, under the hypothesis of distinction and characterization of cotton genotypes, the aim of this study was to evaluate, in three locations, the average behavior of elite breeding lines selected for long fiber, as the agronomic and fiber technological trait. It were evaluated lines derived from a cross between the Guazuncho2 of *Gossypium hirsutum* L. with Acala SJ4 materials of fiber long in three trials located in Apodi-RN in 2013 and 2014 and Santa Helena-GO in 2013. The experimental design was a randomized complete block with two replications. The following traits were evaluated: plant height, average boll weight, percentage of fiber, cotton productivity in seed, fiber length, fiber uniformity, short fiber index, fiber strength, elongation, maturity of the fibers, micronaire, reflectance and the degree of yellowing. The genotypes; Centro Nacional de Pesquisa de Algodão (CNPA) 2012 to 55 and CNPA 2012 to 58 gather high yield and desired fiber characteristics.

Key words: *Gossypium hirssutum*, fiber length, breeding.

INTRODUCTION

Upland cotton (*Gossypium hirssutum* L.r. latifolium Hutch.) is one of the major economically important crops in Brazil. In the country, world's fifth largest cotton producer in seed, with 4.4 million tons in the harvest of 2013/14, the production is concentrated in the Midwest region with 66% of this amount, and the Estado do Mato Grosso is the largest national producer. In the Northeast, the State of Bahia has been highlighted as the largest producer of this crop (Conab, 2015). Changes in spinning technology, competition with synthetic fibers and the globalization of cotton production and textile products increases the demand for higher quality fiber (Smith

*Corresponding author. E-mail: eduteodoro@hotmail.com.

et al., 2008). One of the main traits that still need to be improved is the fiber length (FL). For becoming competitive in the global market, with upland cotton fiber with better quality, industries require greater resistance during spinning and bundling, decrease in the content of short fibers, greater uniformity of length and mature fibers. All these traits are desirable to increasing the processing speed in the textile industry (Smith et al., 2008).

Extra-long staple fiber (ELS) of upland cotton in the United States exhibit a FL value ≥ 32 mm, while pima cottons (*Gossypium barbadense* L.) traditionally are referred to as ELS cotton and the shortest non discount FL is 34.9 mm. Practically 100% of Brazilian upland cotton production is classified as medium FL. Average FL of cotton produced in Brazil in 2013 was 28 mm with little long or extra-long fiber cotton production during the last 10 years. For that reason, it is important that breeding programs focus on the selection of these types of cotton to supply the expected future demand (Carvalho et al., 2015a).

In this way, breeding programs have as a main objective the selection of genotypes with high yields and high quality fiber (Hoogerheide et al., 2007). Thus, under the hypothesis of distinction and characterization of cotton genotypes, the aim of this study was to evaluate, in three sites, the average behaviour of elite breeding lines selected for long fiber, in relation to other agronomic and technology traits of fiber.

MATERIALS AND METHODS

Lines derived from the crossing between Guazuncho 2 from *G. hirsutum* L. with Acala SJ4 of longer fiber were assessed. The seeds were increased from the generation F_2 to F_4. The genealogical selection procedure was adopted from the F_4 generation and in this latest generation 271 F_4 plants were obtained, from which 51 $F_{4:5}$ plants were selected with length ≥ 31 mm; later, in a greenhouse, 34 $F_{5:6}$ lines with length ≥ 32 mm were selected, evaluated and analyzed (Carvalho et al., 2015a). In the remaining lineages, only the lines with length > 32 mm were selected. These lines were evaluated in three trials located at Apodi-RN in 2013 and 2014 and Santa Helena-GO in 2013, in a randomized block design with two replications. Apodi trials were performed under irrigation and in Santa Helena under non-irrigated cultivation.

The plot constitutes two lines of 5m spaced 0.80 m, keeping up to 60 plants per row. Cultural practices were normal for the cotton crop, having used herbicide for weed and pest control according to the integrated management of pests recommendation for the crop in the region.

Evaluated agronomic traits were: plant height (PH cm), average boll weight (ABW, g), percentage of fiber (PF%) and cotton yield in seed (YIE, kg ha^{-1}). At 20 bolls of each experimental unit were evaluated the following technological properties of fibers: fibers length (FL, mm), uniformity of fiber (UNIF%), short fiber index(SFI%), fiber strength (FS, gf tex^{-1}), stretching (STR, %), maturity of fibers (MAT, %), micronaire (MIC, ug pol^{-1}), reflectance (RF, %) and degree of yellowing (+b) using the High volume instrument (HVI) from Fibers Laboratory of Embrapa Cotton.

Data were initially submitted to individual analysis of variance after a joint analysis, the effect of treatments such as fixed and the other effects as random were considered. It was found that the relationship between the largest and smallest mean square of the residue from the individual analysis of variance did not exceed the ratio 7:1, allowing the implementation of joint analysis of trials (Banzatto and Kronka, 2006; Pimentel-Gomes, 2009). Subsequently, the averages were compared by Scott-Knott test at 5% probability of error type I occurrence. All analyzes were performed with the assistance of Genes software (Cruz, 2013).

RESULTS AND DISCUSSION

There were significant difference ($p<0.05$) among cotton genotypes for all traits, allowing to infer about the existence of genetic variability among genotypes (Table 1). Similar results were obtained in other studies with the cotton crop (Carvalho et al., 2015a, b; Jerônimo et al., 2014; Araújo et al., 2013; Martins et al., 2012; Freitas et al., 2007). It is noteworthy that there was no genotype × environment interaction, indicating linearity among environments and the occurrence of similar response of genotypes compared to the environmental effects. Thus, the selection of superior genotypes can be done based on average comparison of evaluated traits (Cruz and Regazzi, 2004).

Plant height (PH) is the trait that has the highest effect on the cotton harvest (Silva et al., 2007), as the harvester platform have a fixed size and plants of genotypes with plant height >1.20 m, as Centro Nacional de Pesquisa de Algodão (CNPA) 2012 to 76, can suffer tipping and kneading by machine, reducing the fiber quality and quantity harvested (Table 2). The average boll weight (ABW), according to Carvalho et al. (2005), is a major component of the cotton plume production, relating linearly with the percentage of fiber. Thus, the genotypes CNPA 2012 to 56, CNPA 2012 to 70, CNPA 2012 to 90 and CNPA 2012 to 91 highlighted by having average boll weight higher than 7.0 g (Table 2).

Fiber length (FL) is measured between the longer half of the fiber bundle into 32 inch subdivisions. This trait affect the strength and uniformity of the yarn, as well as the efficiency of the spinning process. On the other hand, it also influences the purity of a yarn which can be successfully produced from certain fibers (Santana et al., 2008). Based on the criteria established by these authors, most of the genotypes were classified as long fiber, some longer than 30 mm. The genotypes that stood out significantly to this trait in relation to others were CNPA 2012 to 15, CNPA 2012 to 58 and CNPA 2012 to 64 which obtained average values higher than 32 mm (Table 2).

Percentage of fibers (PF) refers to the ratio between

Table 1. Summary of joint analysis of variance for the traits.

Sources of variation	DF	PH	ABW	FL	PF	YIE	FS	MIC
Blocks/Environments	3	849.72^{ns}	2.21^{ns}	12.18^{ns}	62.21^{ns}	2,382,431.86^{ns}	9.31^{ns}	0.01^{ns}
Genotypes (G)	35	600.72*	3.48*	50.18*	90.71*	2,688,557.31*	49.66*	0.03*
Environments (E)	2	21,998.65*	43.63*	188.81*	57.84^{ns}	46,311,651.59*	28.41^{ns}	0.01^{ns}
G × E	70	118.97^{ns}	0.62^{ns}	1.18^{ns}	12.08^{ns}	1,340,192.92^{ns}	2.35^{ns}	0.01^{ns}
Residue	105	291.03	1.16	13.3	29.33	1,547,672.00	16.07	0.01
CV (%)	-	15.98	16.92	12.41	15.24	26.29	13.24	12.05
MSr^+/MSr^-	-	1.88	2.4	1.05	2.4	1.31	1.18	1.01

Sources of variation	DF	SFI	MAT	UNIF	STR	RF	DY
Blocks/Environments	3	0.77	0.01^{ns}	85.88^{ns}	0.71^{ns}	88.77^{ns}	88.77^{ns}
Genotypes (G)	35	3.25*	0.03*	313.46*	4.40*	253.97*	253.97*
Environments (E)	2	7.77*	0.01^{ns}	48.51^{ns}	2.24^{ns}	90.76^{ns}	90.76^{ns}
G × E	70	0.38^{ns}	0.01^{ns}	1.13^{ns}	0.20^{ns}	3.34^{ns}	3.34^{ns}
Residue	105	0.87	0.01	99.61	0.66	88.6	88.6
CV (%)	-	14.05	12.05	11.89	14.29	12.26	12.26
MSr^+/MSr^-	-	1.01	1.01	1.01	1.57	1.03	1.03

^{ns} and *: not significant and significant at 5% probability by F test, respectively. DF (degrees of freedom), MSr (mean square of residue), PH (Plant height), ABW (average boll weight), FL (fiber length), PF (percentage of fiber), YIE (yield of cotton in seed), FS (fiber strength), MIC (micronaire), SFI (short fiber index), MAT (maturity of fibers), UNIF (uniformity of fiber), STR (stretching), RF (reflectance) and DY (degree of yellowing) evaluated in 36 cotton genotypes in three environments in Brazil.

the weight of cotton in lint and the weight of cotton in seed, indicating how much of the total weight is assigned to the fiber. This trait is fundamental to the farmer because it is the proportion of production marketed with greater economic value (Carvalho et al., 2005). The genotypes CNPA 2012 to 56 and CNPA 2012 to 57 obtained average PF higher than 40%, but it had low fiber length (Table 2). There is a negative correlation between the percentage of fiber and fiber length of the longer fiber materials (Carvalho et al., 2015a). However some genotypes showed longer fiber and good percentage of fiber such as; CNPA 2012 to 61, CNPA 2012 to 62, CNPA 102 to 76, CNPA 2012 to 82, CNPA 2012 to 83, CNPA 2012 to 84, CNPA 2012 to 85. Regarding the yield of cotton in seed (YIE), the overall average (Table 2) of the trials is higher than the values observed by Silva et al. (2009) and similar to the values obtained by Hoogerheide et al. (2007).

Fiber strength (FS) is the force in grams required for breaking a bundle of fibers of a textile, which is equivalent to the mass in grams of 1000 metres of fiber. Values higher than 29.0 gf tex^{-1} are required by the textile industry to minimize the breakage of yarns during its processing (Santana et al., 2008). Thus, in exception to the genotype CNPA 2012 to 64, all others were classified as strong based on this trait (Table 2). Micronaire (MIC) is a trait that takes into account the measure of fineness and maturity of the fibers. Based on Santana et al. (2008) classification, genotypes that showed average micronaire degrees were; CNPA 2012 to 68, CNPA 2012 to 55, CNPA 2012 to 76, CNPA 2012 to 82 and CNPA 2012 to 83 (Table 2). These values are required by the textile industry.

The traits short fiber index (SFI) and uniformity of fiber (UNIF) are directly related to the processing and quality of the fibers, and it is expressed in percentage (Table 3). According to Santana et al. (2008), all genotypes were considered uniform, for presenting SFI less than 9% and UNIF higher than 80%. The genotypes CNPA 2012 to 58, CNPA 2012 to 59, CNPA 2012 to 60 and CNPA 2012 to 79 stood out by possessing SFI < 6.20% and 86% of fibers with the same length (Table 3). According to Santana et al. (2008), the maturity (MAT) should be greater than 80% in order to maximize the absorption and retention of the dyes. Thus, the fiber of all genotypes can be considered very mature, by presenting a minimum value of 87%. Stretching trait (STR), which allows checking of the elasticity to the traction of a textile material, indicated that the genotypes CNPA 2012 to 56, CNPA 2012 to 57, CNPA 2012 to 82 and CNPA 2012 to 91 are those with more elongated fibers (Table 3).

Reflectance (RF) measures the amount of light reflected on the sample and all genotypes showed suitable values with RF ≥ 74% (Santana et al., 2008). We noted in Table 3 that for the degree of yellowing (DY), which indicates the degree of pigmentation of colour, all the tested genotypes obtained values acceptable by the textile

Table 2. Average values for the traits.

Genótipos	PH (cm)	ABW (g)	FL (mm)	PF (%)	PROD (kg ha^{-1})	FS (gf tex^{-1})	MIC (µg pol^{-1})
CNPA 2012 -55	118.93^{a}	5.67^{b}	32.78^{a}	31.43^{c}	4,818.17^{a}	32.02^{a}	4.25^{f}
CNPA 2012-56	116.70^{a}	7.52^{a}	27.45^{e}	40.32^{a}	5,346.67^{a}	29.27^{b}	4.63^{d}
CNPA 2012-57	96.27^{c}	6.73^{a}	26.03^{f}	40.78^{a}	3,939.83^{b}	29.40^{b}	5.90^{a}
CNPA 2012-58	109.17^{b}	5.90^{b}	32.37^{a}	37.85^{a}	5,568.50^{a}	30.70^{b}	4.40^{e}
CNPA 2012-59	120.20^{a}	6.17^{b}	31.38^{b}	30.07^{c}	4,061.33^{b}	31.48^{a}	4.43^{e}
CNPA 2012-60	107.97^{b}	6.37^{b}	30.17^{c}	32.97^{c}	5,537.83^{a}	33.70^{a}	5.00^{c}
CNPA 2012-61	103.10^{c}	6.73^{a}	29.27^{d}	38.70^{a}	4,988.50^{a}	30.28^{b}	4.75^{d}
CNPA 2012-62	104.33^{c}	5.88^{b}	31.52^{b}	38.52^{a}	3,973.00^{b}	29.90^{b}	4.68^{d}
CNPA 2012-63	111.77^{b}	6.78^{a}	28.55^{d}	34.12^{b}	4,624.00^{b}	31.47^{a}	5.33^{b}
CNPA 2012-64	106.63^{c}	7.42^{a}	32.00^{a}	35.03^{b}	3,518.83^{b}	28.70^{b}	3.33^{h}
CNPA 2012-65	95.73^{c}	6.98^{a}	29.18^{d}	35.80^{b}	5,718.83^{a}	30.07^{b}	4.45^{e}
CNPA 2012-66	104.37^{c}	6.17^{b}	29.87^{c}	35.93^{b}	3,598.50^{b}	29.52^{b}	4.13^{f}
CNPA 2012-67	100.87^{c}	5.67^{b}	29.53^{d}	36.93^{a}	4,520.83^{b}	29.63^{b}	4.10^{f}
CNPA 2012-68	111.73^{b}	6.32^{b}	31.38^{b}	35.16^{b}	4,839.83^{a}	29.03^{b}	3.78^{g}
CNPA 2012-69	109.77^{b}	6.10^{b}	30.68^{c}	33.07^{c}	4,423.67^{b}	29.97^{b}	4.95^{c}
CNPA 2012-70	115.80^{a}	7.22^{a}	27.67^{e}	35.80^{b}	5,180.67^{a}	30.33^{b}	5.62^{b}
CNPA 2012-71	108.90^{b}	6.45^{b}	28.55^{d}	38.95^{a}	5,186.50^{a}	31.87^{a}	5.43^{b}
CNPA 2012-72	98.63^{c}	6.55^{a}	29.60^{d}	32.68^{c}	4,425.83^{b}	32.85^{a}	5.22^{c}
CNPA 2012-73	116.87^{a}	6.67^{a}	30.42^{c}	34.65^{b}	4,670.83^{b}	32.42^{a}	5.07^{c}
CNPA 2012-74	108.63^{b}	6.28^{b}	30.87^{c}	35.63^{b}	5,328.50^{a}	33.32^{a}	5.00^{c}
CNPA 2012-75	109.73^{b}	6.12^{b}	28.97^{d}	36.67^{a}	3,782.78^{b}	29.58^{b}	4.70^{d}
CNPA 2012-76	126.60^{a}	6.43^{b}	29.83^{c}	38.53^{a}	5,560.00^{a}	31.10^{a}	4.53^{e}
CNPA 2012-77	116.50^{a}	6.80^{a}	28.72^{d}	35.95^{b}	5,413.83^{a}	30.72^{b}	5.37^{b}
CNPA 2012-78	116.23^{a}	5.55^{b}	30.85^{c}	32.72^{c}	5,132.67^{a}	30.87^{b}	4.28^{f}
CNPA 2012-79	107.17^{c}	6.55^{a}	30.87^{c}	33.22^{c}	4,921.83^{a}	32.40^{a}	4.77^{d}
CNPA 2012-80	108.20^{b}	6.18^{b}	30.48^{c}	32.85^{c}	4,927.83^{a}	30.43^{b}	5.05^{c}
CNPA 2012-82	103.93^{c}	6.55^{a}	29.48^{d}	37.15^{a}	4,887.17^{a}	29.87^{b}	4.18^{f}
CNPA 2012-83	103.20^{c}	6.30^{b}	29.95^{c}	38.23^{a}	4,490.83^{b}	30.30^{b}	4.18^{f}
CNPA 2012-84	103.67^{c}	6.90^{a}	29.08^{d}	39.25^{a}	4,283.67^{b}	29.43^{b}	5.23^{c}
CNPA 2012-85	97.83^{c}	5.62^{b}	29.38^{e}	37.68^{a}	4,576.00^{b}	28.88^{b}	4.72^{d}
CNPA 2012-86	95.53^{c}	5.38^{b}	27.45^{e}	38.93^{a}	5,079.67^{a}	29.62^{b}	5.28^{c}
CNPA 2012-87	104.90^{c}	6.53^{a}	31.33^{b}	33.92^{c}	5,271.17^{a}	32.92^{a}	5.13^{c}
CNPA 2012-88	115.10^{a}	6.38^{b}	29.88^{c}	33.50^{c}	5,413.50^{a}	32.75^{a}	5.40^{b}
CNPA 2012-89	104.90^{c}	7.10^{a}	30.80^{c}	35.35^{b}	4,577.67^{b}	31.53^{a}	4.87^{c}
CNPA 2012-90	110.43^{b}	7.18^{a}	28.63^{d}	39.82^{a}	5,272.67^{a}	29.18^{b}	5.55^{b}
CNPA 2012-91	112.13^{b}	7.10^{a}	28.20^{d}	39.57^{a}	5,351.17^{a}	29.55^{b}	5.20^{c}
Mean	108.17	6.45	29.8	36.02	4,786.79	30.67	4.81

Means followed by different letters in the columns differ by Skott-Knott test at 5% probability. Plant height (PH), average boll weight (ABW), fiber length (FL), percentage of fiber (PF), yield of cotton in seed (YIE), fiber strength (FS), micronaire (MIC) evaluated in 36 cotton genotypes in three environments in Brazil.

industry (DY ≤ 8.48). It is worth mentioning that the average values obtained for the technological properties of fiber and yield cotton in seed are higher than those obtained in other studies with cotton genotypes (Jerônimo et al., 2014; Araújo et al., 2013; Martins et al., 2012; Freitas et al., 2007). This, in general, shows that the genetic breeding program from Embrapa Algodão has created genotypes according to the pattern required by

Table 3. Average values for the traits.

Genotype	SFI (%)	MAT (%)	UNIF (%)	STR (%)	RF (%)	DY
CNPA 2012 -55	6.15[c]	90.00[a]	85.37[a]	4.43[e]	75.62[b]	5.98[d]
CNPA 2012-56	6.43[c]	90.00[a]	85.22[a]	7.20[a]	78.40[a]	6.93[c]
CNPA 2012-57	7.53[a]	90.00[a]	83.57[b]	7.25[a]	77.90[a]	7.40[b]
CNPA 2012-58	6.03[c]	88.00[a]	86.20[a]	6.23[b]	79.97[a]	5.87[d]
CNPA 2012-59	6.33[c]	90.00[a]	86.28[a]	5.63[c]	76.42[b]	6.52[d]
CNPA 2012-60	6.15[c]	90.00[a]	86.00[a]	5.27[d]	76.88[b]	6.65[c]
CNPA 2012-61	6.65[c]	90.00[a]	85.33[a]	5.43[c]	77.80[a]	6.72[c]
CNPA 2012-62	6.98[b]	90.00[a]	84.75[b]	5.55[c]	78.28[a]	7.60[b]
CNPA 2012-63	6.58[c]	90.00[a]	85.33[a]	5.52[c]	75.75[b]	7.73[b]
CNPA 2012-64	6.38[c]	82.00[c]	85.35[a]	6.25[b]	79.68[a]	6.47[d]
CNPA 2012-65	7.68[a]	90.00[a]	84.13[b]	6.45[b]	77.68[a]	6.53[d]
CNPA 2012-66	7.00[b]	90.00[a]	85.47[a]	5.98[c]	75.00[b]	8.48[a]
CNPA 2012-67	7.12[b]	90.00[a]	85.12[a]	5.70[c]	76.40[b]	7.57[b]
CNPA 2012-68	7.47[a]	87.00[b]	83.43[b]	6.05[c]	78.63[a]	6.75[c]
CNPA 2012-69	7.02[b]	90.00[a]	84.38[b]	5.28[d]	76.70[b]	6.45[d]
CNPA 2012-70	7.45[a]	90.00[a]	84.00[b]	5.88[c]	76.85[b]	7.73[b]
CNPA 2012-71	6.98[b]	90.00[a]	84.83[a]	5.77[c]	79.13[a]	6.87[c]
CNPA 2012-72	6.32[c]	90.00[a]	85.57[a]	4.68[e]	75.47[b]	7.43[b]
CNPA 2012-73	6.47[c]	90.00[a]	85.50[a]	5.40[c]	77.00[b]	6.77[c]
CNPA 2012-74	6.35[c]	90.00[a]	85.50[a]	4.83[e]	78.43[a]	6.33[d]
CNPA 2012-75	6.84[c]	90.00[a]	85.06[a]	5.93[c]	77.38[a]	7.08[c]
CNPA 2012-76	6.57[c]	90.00[a]	84.07[b]	5.73[c]	78.30[a]	6.87[c]
CNPA 2012-77	6.63[c]	90.00[a]	85.30[a]	5.18[d]	76.53[b]	6.50[d]
CNPA 2012-78	6.67[c]	88.00[a]	85.40[a]	6.03[c]	78.60[a]	6.15[d]
CNPA 2012-79	6.20[c]	90.00[a]	86.80[a]	4.85[e]	78.02[a]	6.47[d]
CNPA 2012-80	6.58[c]	90.00[a]	85.27[a]	5.48[c]	75.38[b]	7.55[b]
CNPA 2012-82	6.80[c]	87.00[b]	84.98[a]	7.05[a]	77.58[a]	6.97[c]
CNPA 2012-83	7.38[a]	90.00[a]	84.45[b]	5.87[c]	79.17[a]	6.48[d]
CNPA 2012-84	6.57[c]	90.00[a]	85.85[a]	5.88[c]	78.23[a]	7.15[b]
CNPA 2012-85	7.72[a]	90.00[a]	83.50[b]	5.73[c]	78.02[a]	7.72[b]
CNPA 2012-86	6.63[c]	90.00[a]	85.45[a]	6.52[b]	76.38[b]	6.57[d]
CNPA 2012-87	6.27[c]	90.00[a]	85.80[a]	4.77[e]	75.15[b]	6.85[c]
CNPA 2012-88	6.48[c]	90.00[a]	85.50[a]	5.22[d]	76.60[b]	7.18[b]
CNPA 2012-89	6.55[c]	90.00[a]	85.90[a]	5.50[c]	78.50[a]	6.80[c]
CNPA 2012-90	7.20[b]	90.00[a]	84.68[b]	5.65[c]	77.12[b]	7.82[b]
CNPA 2012-91	6.58[c]	90.00[a]	85.13[a]	7.37[a]	78.17[a]	6.98[c]
Mean	6.75	89.00	85.14	5.77	77.41	6.94

Means followed by different letters in the columns differ by Skott-Knott test at 5% probability. SFI (short fiber index), MAT (maturity of fibers), UNIF (uniformity of fiber), STR (stretching), RF (reflectance) and DY (degree of yellowing) evaluated in 36 cotton genotypes in three environments in Brazil.

modern textile industry.

Conclusion

The genotypes CNPA 2012 to 55 and CNPA 2012 to 58 had higher productivity of cotton in seed and features of desirable fibers for processing by textile industry.

Conflict of Interests

The authors have not declared any conflict of interests.

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