CROP BREEDING AND APPLIED BIOTECHNOLOGY

ARTICLE

Genetic parameters and selection index in intraspecific cotton lines in a Brazilian semi-arid region

Crop Breeding and Applied Biotechnology
24(2): e475224210, 2024
Brazilian Society of Plant Breeding.
Printed in Brazil
http://dx.doi.org/10.1590/1984-70332024v24n2a23

Jailma Souza Thomaz[1*], Jean Pierre Cordeiro Ramos[2], Rennan Fernandes Pereira[2], Roseane Cavalcanti Santos[2] and José Jaime Vasconcelos Cavalcanti[2]

Abstract: *The climatic and edaphic conditions of the semi-arid Brazilian Northeast region limit the production of several annual crops, including cotton. The aim of this study was to estimate the genetic parameters and select water stress tolerant cotton lines based on yield and fiber quality traits. Twenty cotton lines were evaluated in Alagoinha-PB over two years under rainfed conditions. Individual and joint analysis of variance was performed on the data. Genetic parameters were determined, and lines were selected using the selection index. The lines CNPA SA 2019-115, CNPA SA 2019-185, CNPA SA 2019-109, and CNPA SA 2019-165 were selected for further tests in the region for recommendation of new cultivars. These lines can form new blocks of crosses, together with the BRS 286 check cultivar, as they have the best mean yield and fiber quality values, with the expectation of significant genetic gains.*

Keywords: Gossypium hirsutum *L., plant breeding, drought tolerance, rainfed*

INTRODUCTION

Herbaceous cotton (*Gossypium hirsutum* L.) is of great socioeconomic importance worldwide. Its main product is fiber, used in the textile industry. Cotton is one of the world's main commodities; it is grown in numerous countries in climates ranging from arid and semi-arid to tropical and subtropical (Vidal Neto and Freire 2013). Brazil is the world's fourth largest producer of fibers (behind only India, China, and the USA) and the second largest exporter (ICAC 2023).

The strength of Brazilian cotton production is driven by a high level of technological management, as well as by modern cultivars with a broad genetic base capable of increasing yield and adapting to the environment of various agricultural systems, including those with water restrictions (Rodrigues et al. 2016, Vasconcelos et al. 2020).

Drought is a phenomenon that occurs in various agricultural zones in the world, invariably affecting crop production. From a genetic perspective, drought tolerance is a complex polygenic trait, involving factors associated with physiological, biochemical, and molecular processes that can directly contribute to selection procedures (Mahmood et al. 2019).

***Corresponding author:**
E-mail: jailmathomaz@gmail.com
ORCID: 0000-0001-5905-9451

Received: 27 December 2023
Accepted: 15 March 2024
Published: 20 March 2024

[1] Universidade Estadual da Paraíba, Rua Baraúnas, 351, Universitário, 58429-500, Campina Grande, PB, Brazil
[2] Embrapa Algodão, Rua Oswaldo Cruz, 1143, Centenário, 58428-095, Campina Grande, PB, Brazil

Under water stress, several genes are induced or repressed, promoting complex responses, ranging from the perception of stress to the activation of adaptive strategies (Shinozaki and Yamaguchi-shinozaki 2007). Water deficit (often evident in the semi-arid region) is one of the main problems for cotton, causing greater damage when it occurs in the flowering and fruiting phases, affecting yield and fiber quality (Soares et al. 2020, Zou et al. 2020).

Compared to other crops, cotton has relatively high drought tolerance (Almeida et al. 2017). This trait is related to its ability to expand its root system under moderate water deficit conditions (Khan et al. 2018, Lima et al. 2018). Cotton is thus an extremely important crop under the semi-arid conditions of the Brazilian Northeast region, which is characterized by rainfall irregularities that compromise crop growth and development (Zonta et al. 2016, Almeida et al. 2017).

The species of the genus *Gossypium*, whether *G. hirsutum* subsp. Latifolium or *G. hirsutum* subsp. Marie Gallant, representatives of the herbaceous and Mocó types, respectively, have wide variability in tolerating dry seasons (Vasconcelos et al. 2020). Genotypes of the Mocó type, of perennial cycle, have alleles of great importance for genetic improvement in their genome aiming at drought tolerance. In contrast, the herbaceous type has the most commercial cultivars, due to the cycle, yield, and textile quality of the fibers (Barros et al. 2020).

Genetic improvement has greatly contributed to the development of cultivars that are high-yielding and tolerant to environmental stresses (Vasconcelos et al. 2018, Carvalho et al. 2019). Specifically for the semi-arid environment, breeding strategies are based on the transfer of aggregating traits that can ensure not only plant survival during water stress, through the use of metabolic mechanisms to overcome or minimize its effects, but also early flowering, concentrated fruiting, and a short cycle (Vidal Neto and Freire 2013, Carvalho et al. 2019, Vasconcelos et al. 2020).

This study reports on the genetic parameters and selection index applied to advanced lines ($RC_1F_{3:7}$) of cotton from crosses between parents of the herbaceous × Mocó types, with the objective of selecting cotton genotypes grown on dryland in the Brazilian Northeast, based on agronomic performance and fiber quality.

MATERIAL AND METHODS

The experiments were conducted at the Paraiba Research and Rural Extension Agency (Empaer - Empresa Paraibana de Pesquisa, Extensão Rural e Regularização Terrária) Experimental Station (lat 6°57′ S, long 35°32′42″ W, alt 317 m asl), in Alagoinha, PB, during the 2021 and 2022 rainy crop seasons. A total of 19 advanced lines ($RC_1F_{3:7}$) were evaluated, resulting from the crosses between herbaceous cotton cultivars and Mocó, and subsequent backcrossing to the herbaceous parent, pre-selected for tolerance to water stress: CNPA SA 2019–176, CNPA SA 2019–190, CNPA SA 2019–204, CNPA SA 2019–158, CNPA SA 2019–183, CNPA SA 2019–115, CNPA SA 2019–185, CNPA SA 2019–113, CNPA SA 2019–165, CNPA SA 2019–186, CNPA SA 2019–179, CNPA SA 2019–201, CNPA SA 2019–106, CNPA SA 2019– 109, CNPA SA 2019–170, CNPA SA 2019–206, CNPA SA 2019–73, CNPA SA 2019–48, and CNPA SA 2019–180, plus the cultivar BRS 286 as a check cultivar. This is one of the cultivars most used in the semi-arid region. It has excellent fiber quality and yield, and it was adopted as a parent in the breeding program because it has high capacity for reestablishment after passing through water suppression (Vasconcelos et al. 2020).

The soil of the experimental area is classified as a Nitosol (Embrapa 2013). Plant management practices followed recommendations described in Beltrão and Araújo (2004), and fertilization was based on prior soil chemical analysis. The rainfall volume recorded daily throughout the crop cycle in the 2021 was 374.9 mm and in 2022, 796 mm. Total rainfall was expressed monthly, as shown in Figure 1.

The experiment was conducted in a randomized complete block design (RCBD), with 4 replications. A plot was composed of two 5-m rows, with a between-row spacing of 0.80 m and 7 plants per linear meter, corresponding to a population density of 70 plants per plot.

The following traits were recorded at harvest: seed cotton yield (kg ha^{-1}) – SCY, lint yield (kg ha^{-1}) – LY, lint percentage (%) – LP, fiber length (mm) – UHM, uniformity index (%) – UNF, short fiber index (%) – SFI, fiber strength (gf tex^{-1}) – STR, fiber breaking elongation (%) – ELG, micronaire index – MIC, and spinning consistency index – SCI. The traits of the fibers were obtained by HVI (High Volume Instruments), Uster HVI model 1000, at the Fiber and Yarn Laboratory of Embrapa Algodão from a standard sample of each plot containing 20 cotton bolls.

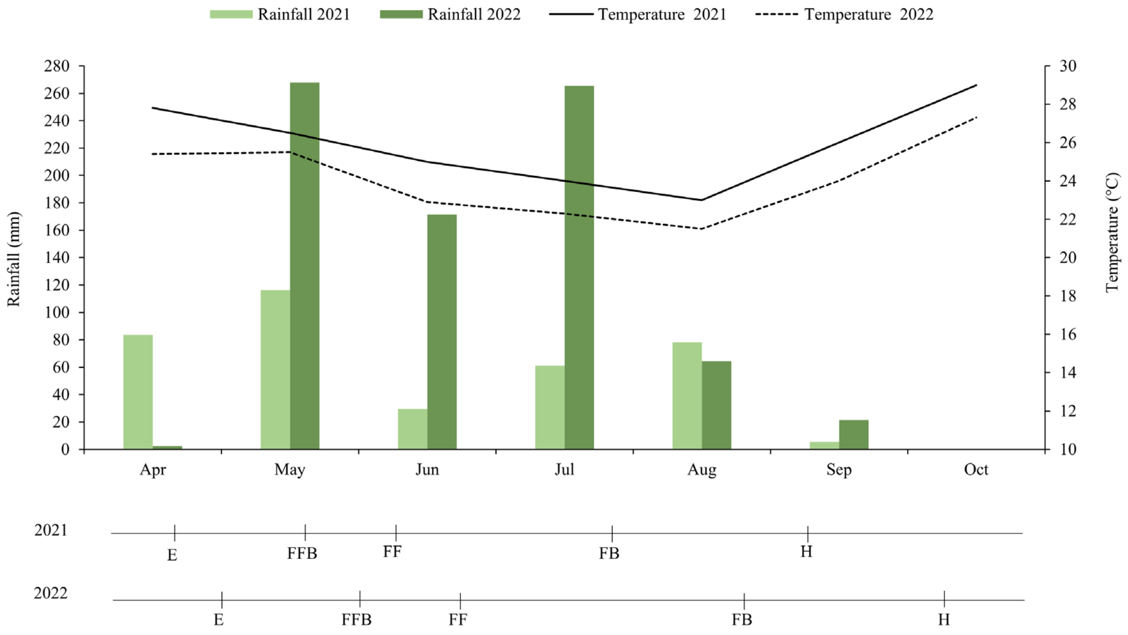

Figure 1. Rainfall and average temperature in Alagoinha, PB, Brazil, in 2021 and 2022 during the cotton cycle. The lines below the graph indicate the phenological stages of the cotton plant in each year. E: emergence; FFB: first flower bud; FF: first flower; FB: first boll; H: harvest.

Statistical analyses were performed using the GENES program, version 1990.2022.27 (Cruz 2013). Lilliefors, Bartlett, and Tukey tests were performed to verify compliance with the assumptions of residual normality, homogeneity of variance, and additivity of the model, respectively.

For the analysis of variance (ANOVA), the effects of genotype and environment (years) were considered as fixed. Individual analyses were performed for each environment, followed by joint analysis of variance, according to the model cited by Cruz et al. (2012):

$$Y_{ijk} = \mu + (B/A)_{jk} + G_i + A_j + GA_{ij} + \varepsilon_{ijK}$$

where Y_{ijk} is observation of the i^{th} genotype evaluated in the k^{th} block and in the j^{th} environment; μ is the overall average; (B/A); jk is the effect of block k within environment j; G_i is the effect of genotype i; A_j is the effect of the environment j; GA_{ij} is the effect of the interaction between genotype i and environment j; and ε_{ijK} is the experimental error associated with the Y_{ijk} observation.

The F-test was calculated and, when significant, means were grouped using the Scott-Knott hierarchical clustering algorithm (Scott and Knott 1974) at 5% probability. The following phenotypic and genetic parameters were evaluated, according to Vencovsky and Barriga (1992) and Cruz (2012): the Genotypic Quadratic Component (Φ_g), Quadratic Component of the Genotype × Environment Interaction (Φ_{gXe}), Coefficient of Genotypic Determination (CGD), Genetic Coefficient of Variation (CV_g), Environmental Coefficient of Variation (CV_e), Relative Coefficient of Variation (CV_g/CV_e).

The selection index proposed by Mulamba and Mock (1978) was used to classify the genotypes in relation to multiple traits, with a selection intensity of 25%. The index is based on the sum of ranks, in which the materials are classified in relation to each of the traits in the sequence favorable to their performance, and subsequently, the positions of each genotype referring to each trait are added, giving rise to the value used as a selection index (Cruz 2012).

RESULTS AND DISCUSSION

The results of joint analysis of variance and the estimates of genetic parameters are shown in Table 1. There was a significant effect ($p \leq 0.05$) among genotypes for all traits evaluated, indicating the existence of variability that can be explored in breeding studies. Among the years evaluated, there was a significant effect for all traits, except UNF and SCI, indicating that the two years had contrasting rainfall availability. The G × Y interaction showed significance for all traits, except for SFI, indicating a differentiated response of the genotypes in the years evaluated; this differentiation was aggravated by the difference in rainfall throughout the development cycle of the genotypes (Figure 1), especially as seen in the accentuated deficiency in 2021.

The estimates of genetic parameters showed that the coefficient of genotypic determination (CGD), analogous to heritability when the model used has fixed effect (Cruz 2012), was high for all traits. Heritability values greater than 70% are considered high, but may vary according to the trait and species evaluated (Bonifácio et al. 2015). Thus, the values found are favorable for the performance of the next generations, with the possibility of desirable genetic gains. Carvalho et al. (2019) evaluated and selected cotton genotypes adapted to semi-arid conditions, and they obtained CGD values higher than 83%.

The (CV_g/CV_e) ratio was higher than one; and the CGD above 89% for the traits LP, UHM, STR, ELG, MIC, and SCI indicated a greater possibility of gain from selection for these traits. According to Bordin et al. (2022), the value of the ratio equal to or greater than 1.0 indicates a favorable condition for selection, because the genetic variance has greater control of the variability between the genotypes than the environmental variance does. Alves et al. (2019) evaluated genotypes of herbaceous cotton in the *agreste* region of Pernambuco under rainfed conditions for two years and obtained the (CV_g/CV_e) values for SCY of 0.64 and 0.71, as well as heritability of 62.19% and 66.69% for the respective years.

Table 2 shows the grouping of agronomic means of the lines. Five lines were classified in the same group as the BRS 286 check cultivar for seed cotton yield (SCY), with means higher than 3485.94 kg ha^{-1} (CNPA SA 2019–186, CNPA SA 2019–179, CNPA SA 2019–185, CNPA SA 2019–204, and CNPA SA 2019–115). Among these, CNPA SA 2019–186 stood out with a LY of 1495.98 kg ha^{-1}, not differing statistically from the check cultivar (1502.66 kg ha^{-1}).

For LP, the best performance levels were observed in the CNPA SA 2019–165 (39.36%), CNPA SA 2019–109 (39.22%), CNPA SA 2019–113 (39.21%), and CNPA SA 2019–183 (38.57%) lines. An LP above 40% is desired by cotton farmers to

Table 1. Summary of joint analysis of variance and estimates of genetic and phenotypic parameters for the traits evaluated in cotton lines under rainfed conditions

SV	Mean squares									
	SCY	**LY**	**LP**	**UHM**	**UNF**	**SFI**	**STR**	**ELG**	**MIC**	**SCI**
B/Y	193239.02	22461.63	2.49	1.22	0.65	0.08	1.76	0.09	0.03	40110.28
G	1103653.09**	223646.23**	64.70**	13.68**	4.83**	1.05**	18.42**	2.49**	0.49**	374130.23**
Y	80258299.79**	12437885.01**	114.86**	39.94**	0.78	2.03**	142.92**	17.68**	3.30**	5034.24
G × Y	1201475.23**	185182.75**	7.48**	1.92**	2.71*	0.42	5.10**	0.48**	0.24**	83119.12**
Error	285533.25	64451.99	1.27	0.78	1.34	0.28	1.98	0.19	0.03	33464.32
Mean	3287.26	1178.09	35.71	30.73	85.85	6.68	33.69	5.50	4.03	3265.23
CV_e (%)	16.26	21.55	3.16	2.87	1.35	7.93	4.18	7.89	4.08	5.60
Genetic parameters										
Φ_g	102264.98	19899.28	7.93	1.61	0.44	0.10	2.05	0.29	0.06	42583.24
Φ_{gy}	228985.49	30182.69	1.55	0.29	0.34	0.03	0.78	0.07	0.05	12413.70
CGD (%)	74.13	81.80	98.04	94.32	72.15	73.33	89.26	92.42	94.48	91.06
CV_g (%)	9.73	11.97	7.89	4.13	0.77	4.65	4.26	9.74	5.97	6.32
CV_g/CV_e	0.60	0.56	2.50	1.44	0.57	0.59	1.02	1.23	1.46	1.13

SCY – seed cotton yield (kg ha^{-1}); LY – lint yield (kg ha^{-1}); LP – lint percentage (%); UHM – fiber length (mm); UNF – uniformity index (%); SFI – short fiber index (%); STR – fiber strength (gf.tex^{-1}); ELG – fiber breaking elongation (%); MIC – micronaire index; SCI – spinning consistency index. ** and * – significant at 1% and 5% probability, respectively, by the F test; SV – source of variation; B/Y – block/year; G – genotype; Y – year; G × Y – genotype × year interaction. Genotypic quadratic component (Φ_g); quadratic component of the genotype × year interaction (Φ_{gy}); coefficient of genotypic determination (CGD); genetic coefficient of variation (CV_g); environmental coefficient of variation (CV_e); relative coefficient of variation (CV_g/CV_e).

obtain greater profit (Cordão Sobrinho et al. 2015). Maniçoba et al. (2021), who evaluated cotton in the semi-arid region, reported values between 36.2% and 43.6% for cotton under water suppression treatments.

Regarding fiber quality traits, selection is based on classification according to textile industry requirements, with the following values: length > 30 mm, uniformity > 84%, short fiber index from 6 to 9 %, resistance > 28 gf tex^{-1}, breaking elongation > 6.7 %, micronaire index from 3.8 to 4.6 (Lima 2018b), and reliability index >2000 (Freire et al. 2015). From the data presented in Table 2, it appears that most of the lines met the requirements for fiber uniformity (UNF), short fiber index (SFI), and breaking elongation (ELG), as well as for the other characteristics discussed below.

For fiber length (UHM), we highlight the genotype CNPA SA 2019–158 (34.21 mm), followed by the genotypes CNPA SA 2019–204 (32.32 mm), CNPA SA 2019–48 (32.06 mm), CNPA SA 2019–185 (31.67 mm), CNPA SA 2019–115 (31.46 mm), and CNPA SA 2019–73 (31.25 mm). Longer fibers function better in the twisting of the yarn and produce less hairy and more resistant yarns (Lima et al. 2007). This affects the economic value of the product, because longer fibers have higher and better quality, giving rise to superior yarns and fabrics (Lima 2018a). Lima et al. (2018) evaluated the effect of water deficit in different phenological stages of cotton in the semi-arid region of Paraíba and observed that the lowest value for UHM was obtained with water deficit in the flower bud phase (30.17 mm). Vasconcelos et al. (2020) analyzed cotton genotypes under water stress and obtained slightly lower fiber length values, ranging from 26.02 mm to 31.97 mm.

As for fiber strength (STR), the outstanding genotype was CNPA SA 2019 –158 (37.27 g tex^{-1}), followed by the genotypes CNPA SA 2019–204, CNPA SA 2019–115, CNPA SA 2019–185, and CNPA SA 2019–186. According to Lima (2018b), cotton fiber is considered resistant when it has a value between 28 and 30 g tex^{-1} and very resistant when the value exceeds 31 g tex^{-1}. Cotrim et al. (2020) obtained values within market requirements, above 28 g tex^{-1}, indicating resistant fibers. A high strength value provides good yield when the spinning process is well regulated, due to the reduced rate of yarn breakage during manufacturing (Bachelier and Gourlot 2018). Albuquerque et al. (2020) selected genotypes of colored cotton for the conditions of the Brazilian semi-arid region and found values above 29 g tex^{-1} for 85% of the genotypes.

For the micronaire index (MIC), only three lines were below that required by the textile industry. This shows the robustness of the parents used in composition of the lines; despite the strong water limitation they faced in 2021, they

Table 2. Clustering of means by the Scott-Knott test (1974) for agronomic and fiber quality traits of cotton lines evaluated under rainfed conditions

Lines		SCY[1]	LY	LP	UHM	UNF	SFI	STR	ELG	MIC	SCI
1	CNPA SA 2019 – 176	2586.98 b	947.48 c	36.74 b	27.63 e	84.61 b	7.36 a	30.37 e	6.17 b	4.11 c	2757.29 f
2	CNPA SA 2019 – 190	3225.57 b	1130.94 b	34.95 c	30.10 d	85.72 b	6.55 a	32.88 c	5.95 c	3.89 d	3205.77 d
3	CNPA SA 2019 – 204	3608.33 a	1245.53 b	34.47 c	32.32 b	86.55 a	6.09 b	35.80 b	4.97 d	4.05 c	3540.51 b
4	CNPA SA 2019 – 158	3135.83 b	1067.43 c	33.84 d	34.21 a	87.68 a	5.73 b	37.27 a	4.55 e	4.30 b	3794.29 a
5	CNPA SA 2019 – 183	3132.29 b	1199.17 b	38.57 a	29.41 d	85.47 b	6.93 a	32.29 d	5.63 c	4.06 c	3066.30 e
6	CNPA SA 2019 – 115	3485.94 a	1307.40 b	37.45 b	31.46 b	87.03 a	6.30 b	35.26 b	4.58 e	4.17 b	3486.15 b
7	CNPA SA 2019 – 185	3653.13 a	1319.99 b	36.14 b	31.67 b	86.36 a	6.54 a	35.15 b	5.04 d	4.06 c	3445.30 b
8	CNPA SA 2019 – 113	3041.15 b	1201.53 b	39.21 a	29.75 d	85.26 b	6.83 a	33.24 c	5.20 d	4.01 c	3127.99 e
9	CNPA SA 2019 – 165	3264.06 b	1285.07 b	39.36 a	30.53 c	85.22 b	6.88 a	33.05 c	5.66 c	4.66 a	3014.14 e
10	CNPA SA 2019 – 186	4139.79 a	1495.98 a	36.07 b	30.45 c	85.23 b	6.76 a	34.52 b	5.54 c	4.12 c	3216.21 d
11	CNPA SA 2019 – 179	3792.19 a	1278.04 b	33.31 d	30.63 c	85.73 b	6.76 a	32.70 c	5.70 c	3.55 e	3291.91 c
12	CNPA SA 2019 – 201	3077.19 b	1146.43 b	36.65 b	30.49 c	86.71 a	6.88 a	34.08 c	5.74 c	4.26 b	3316.45 c
13	CNPA SA 2019 – 106	3192.71 b	1164.87 b	36.59 b	30.71 c	85.30 b	6.80 a	34.15 c	4.99 d	4.12 c	3214.22 d
14	CNPA SA 2019 – 109	2987.50 b	1181.81 b	39.22 a	29.84 d	86.35 a	6.71 a	33.71 c	5.19 d	4.21 b	3235.00 d
15	CNPA SA 2019 – 170	3106.04 b	924.77 c	29.53 f	30.71 c	86.12 a	6.39 b	33.58 c	6.72 a	3.98 c	3293.76 c
16	CNPA SA 2019 – 206	3322.50 b	1135.66 b	33.93 d	30.83 c	86.19 a	6.68 a	33.13 c	5.72 c	3.64 e	3354.48 c
17	CNPA SA 2019 – 73	2863.75 b	880.67 c	30.92 e	31.25 b	84.68 b	7.16 a	33.50 c	5.15 d	3.74 e	3221.98 d
18	CNPA SA 2019 – 48	3123.44 b	984.73 c	31.67 e	32.06 b	85.63 b	6.58 a	33.53 c	5.40 d	3.89 d	3333.34 c
19	CNPA SA 2019 – 180	3126.56 b	1161.75 b	37.16 b	29.90 d	85.37 b	6.96 a	31.45 d	6.10 b	3.91 d	3064.08 e
20	BRS 286 (T)	3880.31 a	1502.66 a	38.43 a	30.65 c	85.84 b	6.77 a	34.08 c	6.12 b	3.82 d	3325.53 c

T – check cultivar. [1] See codes in Table 1. Means followed by the same letter in the column belong to the same group according to the Scott-Knott test (1974).

were able to maintain fiber quality without many fluctuations. Vasconcelos et al. (2020) demonstrated similar results with respect to the low effect of management practices under water limitation. Fibers with values between 3.8 and 4.6 have good performance in the spinning process (Lima 2018b). The MIC indicates the combination of fiber fineness and maturity (Morais et al. 2021). Fibers with low MIC and high values of resistance, maturity, and elongation favor final product yield and quality (Lima 2018a).

Values higher than 2757 were observed for the SCI trait. The best result was obtained by the genotype CNPA SA 2019–158, followed by the genotypes CNPA SA 2019–204, CNPA SA 2019–115, and CNPA SA 2019–185. The SCI is an index composed of the traits of resistance, reliability, and weavability of the fibers. High values are ideal, because the higher the value, the higher the estimated resistance of the yarn (Morais et al. 2021). Carvalho et al. (2019) evaluated eighteen cotton lines under supplementary irrigation and obtained values from 2465.75 to 3338.13. Gomes et al. (2022) presented approximate values, above 2585.50. Both studies were developed for the semi-arid region.

The results obtained for selection of the best lines according to the selection index and their respective gains from selection for the traits evaluated are shown in Table 3. The traits with the most expressive gains from selection were LY (9.81%), LP (6.61%), and SCY (3.76%). The gain for SCY obtained here is lower than that of 5.64% reported by Carvalho et al. (2019), but higher than that of 2.96% reported by Gomes et al. (2022), both in a semi-arid environment. However, these values vary greatly depending on the selection index, the population, and the genotypes selected in each study.

Unfavorable gain occurred only for ELG (-3.14%) and MIC (3.69%), since the industry aims for high ELG and low MIC values. This may be related to the fact that the correlation between LP and MIC was positive and between LP and ELG negative. As most fiber traits presented means within the standards required by the industry, selection prioritized the yield and LP traits, due to their importance for the cotton grower and for the industry. Furthermore, the MIC values of the selected lines remain within the standards established by the textile industry.

It is noteworthy that the different values of gain from selection between traits occur mainly due to factors such as gene linkage (that is, genes favorable to one trait may be linked to unfavorable genes for another trait), genetic variability, heritability, and the environmental effect (Mabrouk 2020). This can also be resolved by selecting individuals with superior values for these traits in future selection programs. The SFI showed negative gain; however, this result is favorable in cotton breeding, since the cotton industry desires lower values.

Ribeiro et al. (2018) evaluated 36 cotton lines with water supplementation and under rainfed conditions using the selection index of Mulamba and Mock (1978) and obtained desirable results, with negative gains for MIC (-7.48%) and positive gains for ELG (6.28%), SCY (5.02%), UHM (3.24%), LP (2.47%), and STR (0.49%). For the SFI trait, the positive gain (0.24%) was undesirable; however, it was considered low.

Table 3. Estimates of the mean of the original population ($\bar{X}_o$), mean of the selected population ($\bar{X}_s$), expected mean of the improved population ($\bar{X}_i$), coefficient of genotypic determination (CGD) and gain from selection (GS) obtained for the 10 traits (See codes in Table 1) evaluated by the selection index of Mulamba & Mock (1978)

Traits	$\bar{X}_o$	$\bar{X}_s$	**CGD (%)**	**GS**	**GS (%)**	$\bar{X}_i$
SCY	3287.26	3454.19	74.13	123.74	3.76	3411.00
LY	1178.09	1319.39	81.80	115.57	9.81	1293.66
LP	35.71	38.12	98.04	2.36	6.61	38.07
UHM	30.73	30.83	94.32	0.10	0.31	30.83
UNF	85.85	86.16	72.15	0.22	0.26	86.07
SFI	6.68	6.64	73.33	-0.03	-0.48	6.65
STR	33.69	34.25	89.26	0.50	1.50	34.19
ELG	5.51	5.32	92.42	-0.17	-3.14	5.34
MIC	4.03	4.19	94.48	0.15	3.69	4.18
SCI	3265.23	3301.22	91.06	32.77	1.00	3298.00
Selected lines: 20 - 6 - 7 - 14 -9						

Based on this selection process, the best lines were CNPA SA 2019–115, CNPA SA 2019–185, CNPA SA 2019–109, and CNPA SA 2019–165, as they exhibited favorable mean values in respect to the requirements of growers and the industry for most traits, as well as simultaneous satisfactory gains from selection for yield and fiber quality. Therefore, these lines offer considerable potential for release as new cultivars for semi-arid environments; however, they should be evaluated in more locations to reliably attest to their adaptation potential and yield stability. Together with the BRS 286 check cultivar, they can also constitute new blocks of crosses to form suitable populations for use in the cotton breeding program for the semi-arid region.

Among these materials, the lines CNPA SA 2019–115 and CNPA SA 2019–165 and the check cultivar BRS 286 also stood out for most of the traits evaluated, especially for SCY and LY in 2021 (data not shown), as the growing conditions in 2021 were of very reduced water availability, lower than plant demand throughout the cycle. As such, these lines may provide even more promising results for growers in the semi-arid region, and they can be the object of future research, since more analyses of years and locations are necessary to confirm the drought tolerance of these materials in the semi-arid region.

ACKNOWLEDGMENTS

Our thanks to Embrapa Algodão and the Empresa Paraibana de Pesquisa, Extensão Rural e Regularização Terrária (Empaer) in Alagoinha/PB for financial support and to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the scholarship provided.

REFERENCES

Albuquerque RRS, Cavalcanti JJV, Farias FJC, Queiroz DR and Carvalho LP (2020) Estimates of genetic parameters for selection of colored cotton fiber. **Revista Caatinga 33**: 253-259.

Almeida ESAB, Pereira JR, Azevedo CAV, Araújo WP, Zonta JH and Cordão MA (2017) Algodoeiro herbáceo submetido a déficit hídrico: Produção. **Agropecuária Científica no Semiárido 13**: 22-28.

Alves FAL, Cavalcante FS, Oliveira Júnior IS, Ferraz I and Silva SMS (2019) Competição de variedades de algodão herbáceo para cultivo no agreste pernambucano. **Pesquisa Agropecuária Pernambucana 24**: 1-8.

Bachelier B and Gourlot JP (2018) A fibra de algodão: origem, estrutura, composição e caracterização. In Belot JL (ed**) Manual de Qualidade da Fibra da AMPA**. IMAmt - Instituto Matogrossense do Algodão, Cuiabá, p. 28-57.

Barros MAL, Silva CRC, Lima LM, Farias FJC, Ramos GA and Santos RC (2020) A review on evolution of cotton in Brazil: GM, white, and colored cultivars. **Journal of Natural Fibers 19**: 209-221.

Beltrão NEM and Araújo AE (2004) **Algodão: o produtor pergunta, a Embrapa responde**. Embrapa Informação Tecnológica, Brasília, 265p.

Bonifácio DOC, Mundim FM and Sousa LB (2015) Variabilidade genética e coeficiente de determinação em genótipos de algodoeiro quanto a qualidade da fibra. **Revista Verde 10**: 66-71.

Bordin PAN, Anjos RSR, Cristeli DS, Garcia TP, Moitinho AKR, Souza JS, Ângelo LC, Cordeiro GS, Mandrá Júnior M and Unêda-Trevisoli SH (2022) Caracterização e fenotipagem agronômica em progênies de soja avaliadas em ensaio preliminar de desempenho. **Open Science Research 7**: 61-71.

Carvalho JF, Cavalcanti JJV, Farias FJC, Ramos JPC, Queiroz DR and Santos RC (2019) Selection of upland cotton for the Brazilian semi-arid region under supplementary irrigation. **Crop Breeding and Applied Biotechnology 19**: 185-192.

Cordão Sobrinho FP, Guerra HOC, Araújo WP, Pereira JR, Zonta JH and Bezerra JR (2015) Fiber quality of upland cotton under different irrigation depths. **Revista Brasileira de Engenharia Agrícola e Ambiental 19**: 1057-1063.

Cotrim MF, Farias FJC, Carvalho LP, Teodoro LPR, Silva Junior CA and Teodoro PE (2020) Phenotypic adaptability of cotton genotypes to the Brazilian cerrado for yield and fiber quality. **Bioscience Journal 6**: 1223-1230.

Cruz CD (2012) **Princípios de genética quantitativa**. Editora UFV, Viçosa, 394p.

Cruz CD (2013) GENES- a software package for analysis in experimental statistics and quantitative genetics. **Acta Scientiarum 35**: 271-276.

Cruz CD, Regazzi AJ and Carneiro PCS (2012) **Modelos biométricos aplicados ao melhoramento genético**. Editora UFV, Viçosa, 514p.

Embrapa - Empresa Brasileira de Pesquisa Agropecuária (2013) **Sistema brasileiro de classificação de solos**. Embrapa Solos, Brasília, 353p.

Freire EC, Morello CL, Farias FJC, Pedrosa MB and Filho JLS (2015) Melhoramento do algodoeiro: cultivares convencionais e transgênicas para o cerrado. In Freire EC (ed) **Algodão no cerrado do Brasil.** ABRAPA, Brasília, p. 151-201.

Gomes IHRA, Cavalcanti JJV, Farias FJC, Paixão FJR, Silva Filho JL and Suassuna ND (2022) Selection of cotton genotypes for yield and fiber quality under water stress. **Revista Brasileira de Engenharia Agrícola e Ambiental 26**: 610-617.

ICAC - International Cotton Advisory Committee (2023) **International Cotton Advisory Committee**. Available at <https://icac.org/

DataPortal/DataPortal?Year=2021/22%20proj>. Accessed on June 12, 2023.

Khan A, Pan X, Najeeb U, Tan DKY, Fahad S, Zahoor R and Luo H (2018) Coping with drought: stress and adaptive mechanisms, and management through cultural and molecular alternatives in cotton as vital constituents for plant stress resilience and fitness. **Biological Research 51**: 2-17.

Lima AKVO, Almeida FAC, Santos JW and Neto JJSB (2007) Características tecnológicas da fibra do algodão 'BRS 200' marrom armazenada em duas microrregiões paraibanas. **Revista Brasileira de Oleaginosas e Fibrosas 11**: 163-171.

Lima JJ (2018a) A indústria têxtil e a qualidade da fibra. In Belot JL (ed) **Safra 2018 - Manual de qualidade da fibra da AMPA**. IMAmt - Instituto Matogrossense do Algodão, Cuiabá, p. 166-191.

Lima JJ (2018b) Classificação do algodão em pluma. In Belot JL **Safra 2018 - Manual de qualidade da fibra da AMPA**. IMAmt - Instituto Matogrossense do Algodão, Cuiabá, p. 58-115.

Lima RF, Araújo WP, Pereira JR, Cordão MA, Ferreira FN and Zonta JH (2018) Fibras de algodoeiro herbáceo sob déficit hídrico. **Revista Verde de Agroecologia e Desenvolvimento Sustentável 13**: 427-436.

Mabrouk AH (2020) Application of some selection procedures for improving of some economic characters in cotton (*G. Barbadense* L.). **Menoufia Journal of Plant Production 5**: 365-383.

Mahmood T, Khalid S, Abdullah M, Ahmed Z, Shah MKN, Ghafoor A and Du X (2019) Insights into drought stress signaling in plants and the molecular genetic basis of cotton drought tolerance. **Cells 9**: 1-30.

Maniçoba RM, Sobrinho JE, Zonta JH, Junior EGC, Oliveira AKS and Freitas IA (2021) Resposta do algodoeiro à supressão hídrica em diferentes fases fenológicas no semiárido brasileiro. **Irriga 26**: 123-133.

Morais JPS, Farias JC, Belot JL, Martins RSA and Mizoguchi ET (2021) Interpretação das características avaliadas no SITC para qualidade de fibra de algodão – Uma abordagem prática. Embrapa Algodão, Campina Grande, 46p. (**Documentos, 285**).

Mulamba NN and Mock JJ (1978) Improvement of yield potential of the Eto Blanco maize (*Zea mays* L.) population by breeding for plant traits. **Egyptian Journal of Genetics and Cytology 7**: 40-51.

Ribeiro LP, Carvalho LP, Farias FJC, Rodrigues JIS, Teodoro PE and Bhering LL (2018) Genetic gains in agronomic and technological traits of elite cotton genotypes. **Bragantia 77**: 466-475.

Rodrigues JD, Silva CRC, Pereira RF, Ramos JPC, Melo Filho PA, Cavalcanti JJV and Santos RC (2016) Characterization of water-stress tolerant cotton cultivars based on plant growth and in activity of antioxidant enzymes. **African Journal of Agricultural Research 11**: 3763-3770.

Scott AJ and Knott MA (1974) A cluster analysis method for grouping means in the analysis of variance. **Biometrics 30**: 507-512.

Shinozaki K and Yamaguchi-shinozaki K (2007) Gene networks involved in drought stress response and tolerance. **Journal of Experimental Botany 58**: 221-227.

Soares LAA, Dias, KMM, Nascimento HM, Lima GS, Oliveira KJA and Silva SS (2020) Estratégias de manejo do déficit hídrico em fases fenológicas do algodoeiro colorido. **Irriga 25**: 656-662.

Vasconcelos UAA, Cavalcanti JJV, Farias FJC, Vasconcelos WS and Santos RC (2018) Diallel analysis in cotton (*Gossypium hirsutum* L.) for water stress tolerance. **Crop Breeding and Applied Biotechnology 18**: 24-30.

Vasconcelos WS, Santos RC, Vasconcelos UAA, Cavalcanti JJV and Farias FJC (2020) Estimates of genetic parameters in diallelic populations of cotton subjected to water stress. **Revista Brasileira de Engenharia Agrícola e Ambiental 24**: 541-546.

Vencovsky R and Barriga P (1992) **Genética biométrica no fito-melhoramento**. Revista Brasileira de Genética, Ribeirao Preto, 496p.

Vidal Neto FC and Freire EC (2013) Melhoramento genético do algodoeiro. In Vidal Neto FC and Cavalcanti JJV (eds) **Melhoramento genético de plantas no Nordeste**. Embrapa, Brasília, p. 49-83.

Zonta JH, Brandão ZN, Sofiatil V, Bezerra IRC and Medeiros JC (2016) Irrigation and nitrogen effects on seed cotton yield, water productivity and yield response factor in semi-arid environment. **Australian Journal of Crop Science 10**: 118-126.

Zou J, Hu W, Li Y, He J, Zhu H and Zhou Z (2020) Screening of drought resistance indices and evaluation of drought resistance in cotton (*Gossypium hirsutum* L.). **Journal of Integrative Agriculture 19**: 495-508.