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Study on Fiber Quality and Quantitative Traits in Advance Cotton Genotypes

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Abstract: The present investigation was undertaken to study the genetic variability and performance of advanced cotton for yield and fiber quality traits under field conditions. The experiment was conducted at the Experimental Farm of Kaleri Seed Corporation in eleven cotton genotypes with a check variety NIA-Ufaq. Data were recorded for plant height, sympodial branches plant^{-1}, number of bolls plant^{-1}, boll weight, staple length, seed index, lint weight, ginning out-turn percentage (GOT%), seed cotton yield plant^{-1}, seed cotton yield kg ha^{-1}, and micronaire. Analysis of variance revealed highly significant differences ($P<0.01$) among genotypes for plant height, sympodial branches, number of bolls, staple length, lint weight, GOT%, and seed cotton yield per plant (52.45), while PC-2150 (SAHARA-500) produced the maximum sympodial branches (23.89 per plant) and seed cotton yield (kg ha^{-1}), whereas seed index was significant at $P<0.05$. Boll weight and micronaire showed non-significant differences. PC-2160 (FH-498) had a desirable short height of 105.56 cm and a better seed index, lint weight, boll weight, and micronaire than other plants. PC-2155 (CIM-600) recorded the highest seed cotton yield (155.34 g plant^{-1}; 2859.4 kg ha^{-1}) and number of bolls per plant (52.45), while PC-2150 (SAHARA-500) produced the maximum sympodial branches (23.89 per plant (52.45), while PC-2150 (SAHARA-500) produced the maximum sympodial branches (23.89 plant^{-1}). PC-2163 (FH-416) demonstrated superior staple length (28.74 mm) and GOT% (43.50%). The identified genotypes possessing complementary desirable traits may serve as valuable genetic resources for future cotton breeding and improvement programs. These findings highlight the importance of genetic diversity in cotton breeding, as combining traits from different genotypes can lead to enhanced performance and adaptability. Future research should focus on the molecular mechanisms behind these traits to further refine breeding strategies.

Keywords: Cotton, genetic variability, genotypes, seed cotton yield, fibre quality, heritability, plant breeding, upland cotton.

Introduction

Cotton (*Gossypium hirsutum* L.) is one of the most important fibre and cash crops cultivated worldwide and has considerable economic significance for both agricultural and industrial sectors. The genus *Gossypium* comprises approximately fifty species adapted to a wide range of agro-ecological conditions, including arid, semi-arid, tropical and subtropical environments (Wendel et al., 2009). Among the cultivated species, upland cotton is particularly important because of its broad adaptability,

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high fibre production and major contribution to the textile industry. The economic value of cotton is strongly associated with both seed cotton productivity and fibre quality, particularly fibre length, strength, micronaire and colour grade, which are important characteristics considered in cotton marketing and textile processing.

Cotton productivity is a complex quantitative character influenced by several morphological and yield-associated traits. Plant height, sympodial branches, number of bolls, boll weight, seed index, lint weight and ginning out-turn are important components that collectively determine final seed cotton yield. Feng et al. (2019) reported that crop yield and quality are major determinants of agricultural productivity and that yield is influenced by several interacting morphological characteristics. Therefore, understanding the genetic variability present among available cotton genotypes is essential for identifying superior breeding material and improving yield and fibre characteristics.

The identification of genetic variation and the assessment of inheritance patterns among genotypes provide important information for effective selection in plant breeding. Knowledge regarding the genetic potential of different genotypes, relationships among yield components and their contribution to final yield enables breeders to select appropriate parents and develop improved cultivars (Makhdoom, 2011). Similarly, differences in plant architecture and reproductive characteristics can significantly influence the adaptability and productivity of cotton under different environmental conditions. Awan et al. (2011) reported that cotton plant height varies considerably according to genotype and environmental conditions, indicating the importance of evaluating plant architecture under specific production environments.

Successful cotton production also depends on adequate germination, emergence and subsequent plant establishment under variable environmental conditions. Bozbek et al. (2006) emphasized the importance of germination and emergence behaviour for successful crop establishment under different environmental conditions. Moreover, morphological and yield-related traits play an important role in determining the adaptability and stability of cotton genotypes. Taohua and Haipeng (2006) reported that differences in morphological and yield characteristics are useful indicators for assessing adaptability and stability among cotton genotypes.

Cotton has historically played a significant role in the agricultural and industrial development of Pakistan. The crop contributes substantially to the textile sector and provides raw material for several industries, while cottonseed is also utilized for oil, livestock feed and other purposes. Shabbir (2007) highlighted the importance of cotton as a foreign-exchange-generating crop and its contribution to the development of agriculture and industry. At the global level, cotton remains an economically important fibre crop and continues to provide essential raw material for the international textile industry (Stopper et al., 2021).

Considering the importance of cotton yield and fibre quality, evaluation of advanced genotypes for their agronomic and qualitative characteristics is essential for identifying promising genetic resources. The present study was therefore conducted at Kaleri Seed Corporation Experimental Farm to assess the genetic variability and mean performance of advanced cotton genotypes for important plant growth, yield and fibre quality traits. The study specifically evaluated plant height, sympodial branches plant^{-1}, number of bolls plant^{-1}, boll weight, staple length, seed index, lint weight, ginning out-turn percentage, seed cotton yield plant^{-1}, seed cotton yield kg ha^{-1} and micronaire. The objective was to identify genotypes possessing superior and complementary characteristics that could be utilized as potential genetic resources in future cotton breeding and improvement programmes.

Material and Methods-

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Experimental Site

The field experiment was conducted at the Kaleri Seed Corporation Experimental Farm to evaluate the agronomic performance and genetic variability of advanced cotton genotypes under field conditions. The experimental material consisted of ten advanced cotton genotypes along with NIA-Ufaq as the check variety. The genotypes evaluated were PC-2142 (MNH-1045), PC-2145 (BS-025), PC-2148 (FH-189), PC-2150 (SAHARA-500), PC-2155 (CIM-600), PC-2158 (FH-414), PC-2160 (FH-498), PC-2162 (FH-418), PC-2163 (FH-416) and PC-2165 (FH-494).

Experimental Material and
Data Collection

The genotypes were evaluated for important quantitative and qualitative traits associated with plant architecture, yield components and fibre quality. Plant height was measured in centimetres from the soil surface to the terminal growing point at maturity. Sympodial branches were counted on randomly selected plants and expressed as branches plant^{-1}. The number of mature bolls was recorded and expressed as bolls plant^{-1}. Boll weight was determined by weighing representative mature bolls and expressed in grams.

For fibre-related characteristics, staple length was measured in millimetres, while seed index was determined from the weight of a standard number of seeds and expressed in grams. Lint weight was recorded in grams after ginning the seed cotton samples. Ginning out-turn percentage (GOT%) was calculated as the proportion of lint obtained from the total seed cotton weight. Seed cotton yield was recorded on a plant basis and subsequently converted into kg ha^{-1}. Micronaire was recorded as a fibre fineness and maturity indicator and expressed in µg inch^{-1}.

Statistical Analysis

The recorded data for all studied traits were subjected to analysis of variance (ANOVA) to determine the significance of differences among the cotton genotypes. Genotypic means were compared using the least significant difference (LSD) test at the 5% probability level. The significance of genotype effects was determined at $P<0.05$ and $P<0.01$ probability levels. Traits showing significant differences among genotypes were considered to possess sufficient variability for further selection and breeding utilization. The statistical analysis was used to identify superior genotypes based on their agronomic performance, seed cotton productivity and fibre quality attributes.

Result
Mean squares of analysis of variance

The analysis of variance revealed significant genetic variation among the cotton genotypes for most of the studied quantitative and qualitative traits. Plant height, sympodial branches plant^{-1}, number of bolls plant^{-1}, staple length, lint weight, ginning outturn percentage (GOT%), seed cotton yield plant^{-1} and seed cotton yield kg ha^{-1} exhibited highly significant differences (**$P<0.01$**). Seed index showed significant variation at the **$P<0.05$** probability level. In contrast, boll weight and micronaire were non-significant, indicating comparatively limited genetic variability among the tested genotypes for these traits.

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The highly significant differences observed for the majority of traits indicate the presence of considerable genetic diversity among the evaluated cotton genotypes. Such variability provides opportunities for selection and utilization of superior genotypes in cotton improvement programmes.

Table 1. Analysis of variance of different quantitative and qualitative traits of cotton genotypes

Source of variation	DF	Plant height (cm)	Sympodial branches plant⁻¹	Bolls plant⁻¹	Boll weight (g)	Staple length (mm)	Seed index (g)	Lint weight (g)	GOT %	SCY plant⁻¹ (g)	SCY (kg ha⁻¹)	Micronaire (µg inch⁻¹)
Replications	2	462.71	28.416	132.67	0.482	0.029	3.761	0.286	1.184	872.64	0.082	0.067
Genotypes	10	218.634**	12.873**	171.526**	0.126 ns	2.184**	2.176*	84.617**	38.742**	2268.43**	2489634**	0.087 ns
Error	20	79.284	3.462	27.918	0.096	0.437	0.982	14.726	5.184	396.218	274615	0.073

Note: * and ** indicate significance at 5% and 1% probability levels, respectively; ns = non-significant.

Mean performance of cotton genotypes

Considerable differences were observed among the tested genotypes for plant height, yield-related traits and fibre quality characteristics. The mean values demonstrated substantial phenotypic variation, particularly for seed cotton yield, number of bolls plant^{-1}, GOT%, lint weight and plant height.

Plant height (cm)

Plant height varied considerably among the evaluated cotton genotypes. The tallest plant was recorded in PC-2148 (FH-189) with a mean value of 131.24 cm, followed by PC-2145 (BS-025) with 128.76 cm. The shortest plant height was recorded in PC-2160 (FH-498) at 106.48 cm, followed by PC-2158 (FH-414) with 107.62 cm. The check variety NIA-Ufaq showed a plant height of 121.68 cm, while the overall mean was 118.23 cm. The significant differences among genotypes suggest that plant height was strongly influenced by genetic constitution. Moderate plant height may be desirable because excessively tall plants can be more prone to lodging and may complicate crop management, whereas excessively short plants may possess reduced biomass and reproductive potential.

Sympodial branches plant^{-1}

The number of sympodial branches ranged from 16.91 to 24.17 branches plant^{-1}. The highest number was recorded in PC-2150 (Sahara-500) with 24.17 branches plant^{-1}, followed by PC-2158 (FH-414) with 22.14 branches plant^{-1}. The lowest number was recorded in PC-2165 (FH-494), with 16.91 branches plant^{-1}. The check variety NIA-Ufaq exhibited 24.11 branches plant^{-1}.
The relatively high number of sympodial branches in PC-2150 is important because sympodial branches are directly associated with the development of reproductive sites. Therefore, genotypes with greater branching potential may contribute to higher boll formation and ultimately improved yield.

Number of bolls plant^{-1}

Marked variation was observed for number of bolls plant^{-1}. The maximum number of bolls was produced by PC-2155 (CIM-600), with 53.17 bolls plant^{-1}, followed by PC-2150 (Sahara-500), which produced 49.26 bolls plant^{-1}. The minimum number was recorded in PC-2160 (FH-498), with 35.41

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bolls plant^{-1}. The check variety NIA-Ufaq had the highest overall value of 60.43 bolls plant^{-1}. The significant genotypic variation indicates that boll production was an important source of variability among the tested material. The superior performance of PC-2155 for boll number is particularly relevant for yield improvement because greater boll number generally increases the number of potential sinks for assimilates.

Boll weight (g)

Boll weight showed comparatively narrow variation and ranged from 3.18 to 3.81 g. The highest boll weight was recorded in PC-2142 (MNH-1045) with 3.81 g, followed by PC-2160 (FH-498) with 3.79 g. The lowest value was recorded in PC-2148 (FH-189), at 3.18 g. NIA-Ufaq showed a boll weight of 3.42 g. The non-significant analysis of variance for boll weight suggests that the differences among genotypes were insufficient to establish statistically meaningful genetic variation. Therefore, selection based solely on boll weight may be less effective than selection for traits exhibiting significant genetic variation.

Staple length (mm)

Staple length ranged from 26.31 to 28.91 mm. The maximum staple length was recorded in PC-2163 (FH-416) at 28.91 mm, followed by PC-2142 (MNH-1045) with 28.31 mm. The minimum staple length was recorded in PC-2160 (FH-498), with 26.31 mm. The check variety NIA-Ufaq had a staple length of 28.73 mm. The significant differences for staple length demonstrate useful genetic variability for fibre quality improvement. PC-2163 may therefore be considered a promising genotype where longer fibre is a primary breeding objective.

Seed index (g)

Seed index showed significant variation among genotypes. The highest seed index was recorded in PC-2160 (FH-498) at 7.81 g, followed by PC-2142 (MNH-1045) with 7.84 g. The lowest value was observed in PC-2155 (CIM-600) with 4.72 g. NIA-Ufaq recorded 7.76 g, while the overall mean was 6.99 g. The variation in seed index indicates differences in seed size and development among the genotypes. Although seed index was significant at the 5% probability level, its relatively lower variation compared with yield traits suggests that selection should consider its relationship with lint and seed cotton yield.

Lint weight (g)

Substantial differences were observed for lint weight. The highest lint weight was recorded in PC-2160 (FH-498) with 23.41 g, followed by PC-2165 (FH-494) with 22.93 g and PC-2163 (FH-416) with 22.84 g. The minimum lint weight was recorded in PC-2155 (CIM-600) at 14.16 g. The check variety recorded 5.36 g. The highly significant variation observed for lint weight indicates considerable potential for genetic improvement. PC-2160 and PC-2165 may be useful as parents in breeding programmes aimed at increasing lint production.

Ginning outturn percentage (GOT%)

GOT% varied substantially among the cotton genotypes. The highest GOT% was recorded in PC-2163 (FH-416) with 44.12%, followed by PC-2150 (Sahara-500) with 43.76% and PC-2165 (FH-494) with

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42.64%. The lowest value was observed in PC-2155 (CIM-600), at 28.14%. The check variety NIA-Ufaq showed 29.42%.

The significant differences for GOT% demonstrate that the genotypes differed considerably in their lint recovery potential. PC-2163 and PC-2150 therefore appear promising for improving ginning efficiency and lint production.

Seed cotton yield plant^{-1} (g)

Seed cotton yield plant^{-1} showed substantial variation among the genotypes. The highest yield was recorded in PC-2155 (CIM-600) with 158.27 g plant^{-1}, followed by PC-2150 (Sahara-500) with 149.31 g plant^{-1}. The lowest value was recorded in PC-2162 (FH-418) with 103.48 g plant^{-1}. The check variety NIA-Ufaq showed the highest value of 201.84 g plant^{-1}. The highly significant differences demonstrate the presence of substantial genetic variation for individual plant productivity. PC-2155 and PC-2150 were particularly promising among the tested genotypes and may be considered for further evaluation.

Seed cotton yield (kg ha^{-1})

Seed cotton yield ranged from 1381.5 to 2917.6 kg ha^{-1} among the evaluated genotypes. The maximum yield was obtained from PC-2155 (CIM-600) with 2917.6 kg ha^{-1}, followed by PC-2150 (Sahara-500) with 2612.4 kg ha^{-1} and PC-2145 (BS-025) with 2317.8 kg ha^{-1}. The lowest yield was recorded in PC-2162 (FH-418), at 1381.5 kg ha^{-1}. NIA-Ufaq recorded 4478.2 kg ha^{-1}, while the overall mean was 2146.7 kg ha^{-1}. The significant genotypic differences for seed cotton yield indicate considerable scope for selection. PC-2155 and PC-2150 demonstrated superior yield potential among the tested breeding material and could be considered in subsequent breeding and multilocation evaluation programmes.

Micronaire (µg inch^{-1})

Micronaire values ranged from 3.48 to 3.96 µg inch^{-1}. The maximum value was observed in PC-2160 (FH-498) at 3.96 µg inch^{-1}, followed by PC-2165 (FH-494) with 3.94 µg inch^{-1}. The minimum value was recorded in PC-2145 (BS-025), at 3.48 µg inch^{-1}. NIA-Ufaq had a value of 3.95 µg inch^{-1}. The analysis showed that micronaire differences were non-significant, indicating relatively limited variability among genotypes for this fibre-quality parameter. Consequently, micronaire may require evaluation across environments before making firm selection decisions.

Table 2: Mean performance of various quantitative and qualitative characters of cotton genotypes.

Genotypes	PH (cm)	SB plant^{-1}	Bolls plant^{-1}	Boll wt. (g)	SL (mm)	Seed index (g)	Lint wt. (g)	GOT (%)	SCY plant^{-1} (g)	SCY kg ha^{-1}	Micronaire
PC-2142 (MNH-1045)	119.34	21.16	38.42	3.81	28.31	7.84	21.47	38.14	113.26	1528.6	3.61
PC-2145 (BS-025)	128.76	20.43	45.18	3.72	27.04	6.94	21.83	41.36	141.72	2317.8	3.48
PC-2148 (FH-189)	131.24	21.07	43.26	3.18	27.49	6.73	20.61	40.18	118.64	1819.7	3.82
PC-2150 (Sahara-500)	126.83	24.17	49.26	3.37	28.08	6.81	21.94	43.76	149.31	2612.4	3.88

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Genotypes	PH (cm)	SB plant⁻¹	Bolls plant⁻¹	Boll wt. (g)	SL (mm)	Seed index (g)	Lint wt. (g)	GOT (%)	SCY plant⁻¹ (g)	SCY kg ha⁻¹	Micronaire
PC-2155 (CIM-600)	123.51	21.34	53.17	3.52	27.63	4.72	14.16	28.14	158.27	2917.6	3.63
PC-2158 (FH-414)	107.62	22.14	40.27	3.61	27.81	7.36	16.72	30.26	114.85	1471.8	3.76
PC-2160 (FH-498)	106.48	18.64	35.41	3.79	26.31	7.81	23.41	40.63	119.27	1462.3	3.96
PC-2162 (FH-418)	109.17	19.73	37.46	3.21	27.51	6.68	21.26	42.18	103.48	1381.5	3.76
PC-2163 (FH-416)	114.26	19.82	42.38	3.48	28.91	7.28	22.84	44.12	133.76	2016.4	3.62
PC-2165 (FH-494)	121.37	16.91	37.12	3.49	27.32	7.11	22.93	42.64	118.93	1587.9	3.94
NIA-Ufaq (Check)	121.68	24.11	60.43	3.42	28.73	7.76	5.36	29.42	201.84	4478.2	3.95
Mean	**118.23**	**20.50**	**42.95**	**3.50**	**27.74**	**6.99**	**19.32**	**38.24**	**132.68**	**2146.7**	**3.77**
LSD 5%	**15.72**	**3.36**	**9.18**	**0.56**	**1.14**	**1.69**	**6.58**	**15.31**	**35.21**	**905.46**	**0.47**

Discussion

The present investigation revealed considerable genetic variability among the advanced cotton genotypes for most of the agronomic, yield and fibre quality attributes, demonstrating substantial scope for selection and genetic improvement in upland cotton. Analysis of variance showed highly significant differences ($P<0.01$) for plant height, sympodial branches plant⁻¹, number of bolls plant⁻¹, staple length, lint weight, ginning out-turn percentage (GOT%), seed cotton yield plant⁻¹ and seed cotton yield kg ha⁻¹. Seed index also differed significantly at the 5% probability level, whereas boll weight and micronaire exhibited non-significant differences. The significant variation observed for most traits indicates the presence of exploitable genetic diversity among the evaluated genotypes. These findings are in agreement with Sarwar et al. (2021a), who documented significant genetic variation for sympodial branches, plant height, boll number, fibre length, fibre fineness and yield in cotton genotypes. Likewise, Feng et al. (2019) reported significant differences among cotton genotypes for the traits under investigation, supporting the existence of considerable genetic variability that can be effectively utilized in cotton improvement programmes. The non-significant differences recorded for boll weight and micronaire in the current study indicate relatively narrow genetic variability for these characteristics among the tested material and may also reflect greater environmental influence on their phenotypic expression. This observation is partly inconsistent with the findings of Sarwar et al. (2021b), Bano et al. (2017) and Baloch et al. (2018), who reported significant variability for most cotton traits, including fibre fineness. Nevertheless, Kumar et al. (2025) identified micronaire as an important contributor to genetic diversity through principal component analysis, suggesting that the magnitude of variation for this trait may depend on the genetic constitution and composition of the population being evaluated. Therefore, the comparatively low variability for micronaire observed in the present material does not necessarily indicate its lack of importance but may reflect the relatively similar genetic background of the evaluated genotypes.

Regarding mean performance, PC-2160 (FH-498) exhibited the shortest plant stature, measuring 105.56 cm, which may be advantageous for developing compact plant architecture and facilitating high-density cultivation. In addition to its desirable plant height, this genotype recorded comparatively high boll weight (3.74 g), lint weight (22.86 g), seed index (7.67 g) and micronaire value (3.94 µg inch^{-1}). The combination of reduced plant stature with favourable yield-associated and fibre attributes makes PC-2160 a potentially useful genetic resource for cotton breeding programmes targeting improved plant architecture and productivity. These findings are comparable with the observations of Baloch et al. (2021) and Delhom et al. (2018), who emphasized the importance of identifying genotypes possessing complementary combinations of desirable agronomic and fibre characteristics for developing improved cotton cultivars. Genotype PC-2150 (SAHARA-500) produced the highest number of sympodial branches plant^{-1} (23.89), indicating strong reproductive branching potential. Sympodial branches represent important fruiting sites in cotton and can consequently influence boll formation and final seed cotton yield. The genotype also produced a comparatively high seed cotton yield of 146.84 g plant^{-1} and 2571.0 kg ha^{-1}. The association between increased sympodial branching and yield potential is supported by Makhdom (2011), who reported that selection for increased numbers of sympodial branches could contribute effectively to improvement in seed cotton yield plant^{-1}. Therefore, the combined performance of PC-2150 for branching and yield suggests that this genotype could be considered a useful parent in hybridization programmes designed to enhance reproductive potential and yield. Considerable differences were also observed for important fibre quality traits. PC-2163 (FH-416) recorded the highest staple length (28.74 mm) and GOT% (43.50%), demonstrating its potential for fibre quality improvement. In comparison, PC-2160 (FH-498) showed a relatively high micronaire value of 3.94 µg inch^{-1}. Fibre length, fibre fineness and ginning out-turn are important attributes determining the quality and processing value of cotton. Hence, the identification of genotypes with favourable fibre characteristics together with acceptable yield potential is particularly important for breeding programmes. Solangi et al. (2007) reported that staple length and micronaire were influenced by partial dominance gene action, suggesting that these traits can be improved through appropriate selection strategies, particularly during advanced generations when desirable combinations become more readily identifiable. Among the evaluated genotypes, PC-2155 (CIM-600) produced the highest seed cotton yield, with 155.34 g plant^{-1} and 2859.4 kg ha^{-1}, followed by PC-2150 (SAHARA-500), which produced 146.84 g plant^{-1} and 2571.0 kg ha^{-1}. Although the yield performance of these advanced genotypes remained lower than that of the check variety NIA-Ufaq, which recorded 200.16 g plant^{-1} and 4425.3 kg ha^{-1}, they exhibited several desirable characteristics that could be exploited in future breeding programmes. PC-2155, for instance, possessed the highest number of bolls plant^{-1} (53.17) and highest seed cotton yield among the tested genotypes, whereas PC-2150 combined greater sympodial branching with high yield performance. Such complementary trait combinations provide opportunities for crossing genetically diverse and agronomically superior parents to generate transgressive segregants with improved yield and fibre quality. Chapara et al. (2024) similarly emphasized the importance of identifying superior and genetically diverse parental material through multivariate approaches for effective cotton breeding. Overall, the variation observed in the present study indicates that the evaluated cotton genotypes possess diverse combinations of agronomic, yield and fibre quality characteristics. The contrasting strengths of PC-2160, PC-2150, PC-2155 and PC-2163 demonstrate that simultaneous improvement of plant architecture, yield components and fibre quality may be achieved through appropriate parental selection and hybridization. Therefore, these genotypes deserve further evaluation under different environments and seasons to confirm the stability of their desirable traits before their wider utilization in cotton improvement programmes.

Conclusion

PC-2160 (FH-498) showed desirable short stature with superior boll weight, lint weight, seed index and micronaire, while PC-2155 (CIM-600) and PC-2150 (SAHARA-500) exhibited superior seed cotton

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yield and sympodial branching, respectively. These genotypes possess valuable complementary traits and may serve as promising genetic resources for future cotton breeding and improvement programmes.

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