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Correlation and path analysis of yield and fibre quality traits in upland cotton (*Gossypium hirsutum* L.)

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Abstract
This investigation aimed to analyze correlations and conduct path analysis of yield and fibre quality traits in American cotton (*Gossypium hirsutum* L.). Fifty diverse elite cotton genotypes, including four check varieties, were cultivated in a Randomized Block Design with two replications during the 2022-23 kharif season at the Cotton Research Station, Nanded. Correlation coefficients played a pivotal role in elucidating trait associations, with genotypic correlation generally surpassing phenotypic correlation, revealing inherent trait relationships. This understanding is crucial for crop enhancement programs, offering insights into the relative contributions of each trait to overall yield. Correlation analysis revealed significant positive genotypic and phenotypic correlations between plant height, number of bolls per plant, boll weight, fibre fineness, and seed cotton yield per plant. Path coefficient analysis determined direct and indirect trait effects on seed cotton yield per plant, emphasizing traits such as the number of bolls per plant, plant height, ginning percentage, lint index, uniformity ratio, and fibre strength, which directly and positively impacted yield. Consequently, these attributes merit priority in selecting high-yielding American cotton genotypes. The study underscored that the number of bolls per plant, plant height, boll weight, number of sympodia per plant, ginning percentage, lint index, and fibre fineness were pivotal for effectively selecting superior American cotton genotypes.

Keywords: American cotton, correlation, path coefficient analysis, correlation coefficient

Introduction

Cotton has been referenced in ancient Indian Vedas, indicating the Vedic people's familiarity with weaving techniques. *Gossypium hirsutum* L., commonly known as cotton, is primarily cultivated for its fibre and oil, playing a pivotal role in the nation's economy. Roughly 64% of the total cotton lint fibre is utilized in the apparel industry, 28% in household furnishings, and 8% in various industrial applications. Moreover, cotton is the most lucrative non-food crop, supporting the USD 3 trillion global fashion industry, with USD 1.3 trillion in global garment exports in 2019. It is recognized globally as a vital fibre crop and is grown as an annual crop in tropical and subtropical regions worldwide. In India, cotton cultivation is prominent in three distinct agro-ecological zones: the Northern zone (Punjab, Haryana, and Rajasthan), the Central zone (Gujarat, Maharashtra, and Madhya Pradesh), and the Southern zone (Andhra Pradesh, Tamil Nadu, and Karnataka). India, along with China, the United States, and Brazil, accounts for 75% of the world's cotton production. India ranks first in cottonseed production globally. The total cultivated area for cotton in India is approximately 126.14 lakh hectares, with a productivity of about 439 kg/ha. In the 2022-23 season, India produced 337 lakh bales of cotton. Maharashtra leads in cotton cultivation area, Gujarat in yield, and Tamil Nadu in production. The cotton genus *Gossypium* encompasses 50 species, including 45 diploids ($2n = 2x = 26$) and 5 tetraploids ($2n=4x=52$), distributed worldwide. Among these species, four are commercially cultivated: *Gossypium arboreum*, *Gossypium herbaceum*, *Gossypium hirsutum*, and *Gossypium barbadense*. The latter two species are tetraploids, with centers of variability in Mexico-Central America and South America. *G. hirsutum* (American cotton) and *G. barbadense* (Egyptian cotton) are referred to as new world cotton. The remaining 46 species are wild and not cultivated. Of all the species identified worldwide, 45 are diploids (Desi Cotton), and the remaining five are tetraploids (American Cotton).

India stands out as the only country cultivating all four commercially viable Gossypium species: *G. arboreum* and *G. herbaceum* (Asiatic cotton), *G. barbadense* (Egyptian cotton), and *G. hirsutum* (American upland cotton), alongside hybrid cotton. *Gossypium hirsutum*, also known as upland cotton or Mexican cotton, is the most extensively planted species globally. Approximately 90% of global cotton production comes from cultivars of this species. Varieties with longer fibres are termed "long-staple upland," while those with shorter fibres are known as "short-staple upland." *G. hirsutum* L. (American cotton) and *G. barbadense* L. (Egyptian cotton) are renowned for their superior fibre quality. In India, 99.9% of hybrid cotton is represented by *G. hirsutum*, and all current Bt cotton hybrids are either *G. hirsutum* or inter-specific hybrids with *G. barbadense*. Correlation analysis serves as a useful index for predicting corresponding changes that occur in a particular character in proportion to others. Correlation coefficient analysis measures the mutual relationships between various plant traits and determines the component characters that can be used for selection to improve yield. Understanding the correlation between important characteristics is necessary for selecting genotypes with high yield and fiber performance. Genetic correlation values offer a measure of the genetic inter-relationship between characteristics, explaining the degree of relationship between traits genetically and phenotypically. The phenotypic variance of a trait can be partitioned into environmental and genetic components. Correlation studies provide a better understanding of the associations between highly heritable characters and economic traits, shedding light on the contribution of each trait in the genetic makeup of the crop. Path analysis is a standardized partial regression coefficient that divides the correlation coefficient into measures of the direct and indirect effects of a set of independent variables on the dependent variable. Path analysis helps determine whether the association of certain characters with yield is due to their direct effect on yield or if it is an indirect effect through other traits. If the correlation between yield and a character is primarily due to the direct effect of that character, it reflects a true relationship for yield improvement. However, if the correlation is mainly due to the indirect effect of the character through another component trait, breeders need to select the trait through which the indirect effect is exerted. The present research aims to study the correlation, and path analysis in upland cotton (*Gossypium hirsutum* L.) for yield contributing and fiber quality traits.

Materials and Methods

The current study involved forty-six diverse genotypes of cotton (*Gossypium hirsutum* L.), along with four standard checks, obtained from various sources, as depicted in Table 1. The experiment took place at the Cotton Research Station in Nanded during the Kharif season of 2022-23. These elite genotypes of *G. hirsutum* were planted in plots using a Randomized Block Design, with two replications, and two rows per genotype per plot, each plot measuring 1.2 x 4.5 square meters. Row spacing was set at 60 cm, with 30 cm between each plant. The four standard checks included PH 348, NH 545, NH 615, and Suraj, obtained from CRS Nanded and CICR Nagpur, respectively.

Table 1: Experiment material

Sr. No.	Genotypes	Source	Sr. No.	Genotypes	Source
1	SCS 793	UAS, Siruguppa	26	GBHV 180	NAU, Bharuch
2	SCS 1061	UAS, Siruguppa	27	GBHV 170	NAU, Bharuch
3	DSC 55	UAS, Dharwad	28	GBHV 198	NAU, Bharuch
4	DSC 1351	UAS, Dharwad	29	CNH 1122	CICR, Nagpur
5	BS 41	OUAT,Bhawanipatna	30	CNH 1137	CICR, Nagpur
6	BS 2	OUAT,Bhawanipatna	31	CNH 2050	CICR, Nagpur
7	CCH 2629	CICR, Coimbtore	32	CNH 15	CICR, Nagpur
8	CCH 1110	CICR, Coimbtore	33	G.Cot 18	NAU, Surat
9	ARBC 757	UAS,Arbhavi	34	G.Cot 22	NAU, Surat
10	ARBC 64	UAS,Arbhavi	35	BWR-152-1	MPUAT, Banswara
11	ARBC 1352	UAS,Arbhavi	36	RB 611	MPUAT, Banswara
12	TCH 5811	TNAU, Coimbatore	37	RB 616	MPUAT, Banswara
13	TSH 0430	TNAU, Srivilliputur	38	NH 688	CRS, Nanded
14	RAH 101	UAS, Raichur	39	NH 662	CRS, Nanded
15	RAH 1271	UAS, Raichur	40	PH 1060	VNMKV, Parbhani
16	AKH 2013-2	Dr. PDKV, Akola	41	PH 1070	VNMKV, Parbhani
17	AKH 2016-1	Dr. PDKV, Akola	42	RHC-HD 1405	MPKV, Rahuri
18	ADB 102	PJTSAU, Adilabad	43	RHC-HD 1312	MPKV, Rahuri
19	KH 113	RVSKKV, Khandwa	44	L 1536	Lam, Guntur
20	IH 71	RVSKKV, Indore	45	NDLH 2061-1	ANGRAU, Nandyal
21	IH 11	RVSKKV, Indore	46	NDLH 2071-1	ANGRAU, Nandyal
22	H 1236	CCSHAU, Hisar	47	PH 348	CRS, Nanded (Standard check)
23	NDLH 1943	ANGRAU, Nandyal	48	NH 545	CRS, Nanded (Standard check)
24	ARBH 83	UAS, Arbhavi	49	NH 615	CRS, Nanded (Standard check)
25	ARBH 813	UAS, Arbhavi	50	Suraj	CICR, Nagpur (Standard check)

Cultivation practices and plant protection measures were implemented according to recommended guidelines, with efforts directed towards maintaining experimental plots free from weeds and pests. In each plot and replication, five plants were randomly selected for observation of thirteen characteristics, including Days to 50% flowering, Plant height (cm), Number of sympodia per plant, Number of bolls per plant, Boll weight (g), Seed index (g), Lint index, and Ginning percentage (%). Fiber quality traits such as upper half mean length (mm), fibre strength (g/tex), fibre fineness (µg/inch), and uniformity ratio (%) were evaluated using the high-volume instrument (HVI) in the well-equipped laboratory of CICR, Nagpur. Mean values for all characters within each replication were subjected to statistical analysis. Analysis of variance was conducted to assess the significance of genotype differences across all characters. In order to study the extent of association between different traits, the genotypic and phenotypic simple correlation coefficients were worked out from the respective variances and covariances. The formulae as suggested by Johnson *et al.*, (1955) were used for calculating simple correlation coefficients. The genotypic correlation coefficients between yield and its components were further partitioned into direct and indirect effects with the help of path coefficient analysis given by Dewey and Lu (1959) [13].

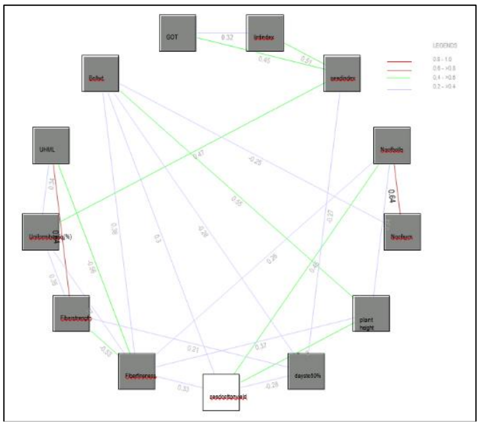

Fig 1: Genotypic correlation matrix for thirteen characters in American cotton

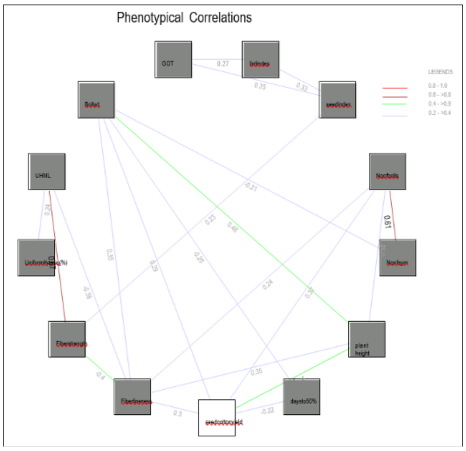

Fig 2: Phenotypic correlation matrix for thirteen characters in American cotton

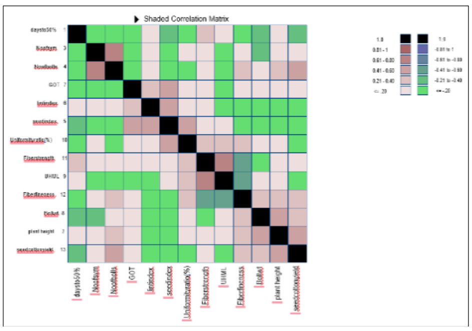

Fig 3: Shaded genotypic correlation matrix for thirteen characters in American cotton

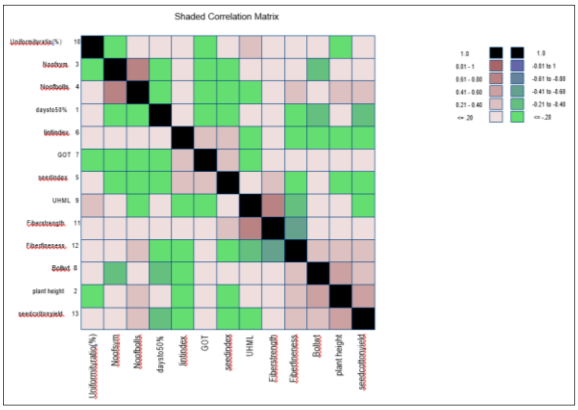

Fig 4: Shaded phenotypic correlation matrix for thirteen characters in American cotton

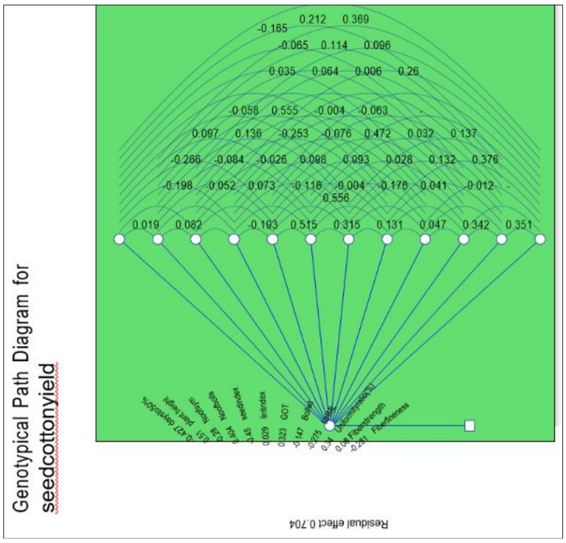

Fig 5: Genotypical path diagram of seed cotton yield in American cotton

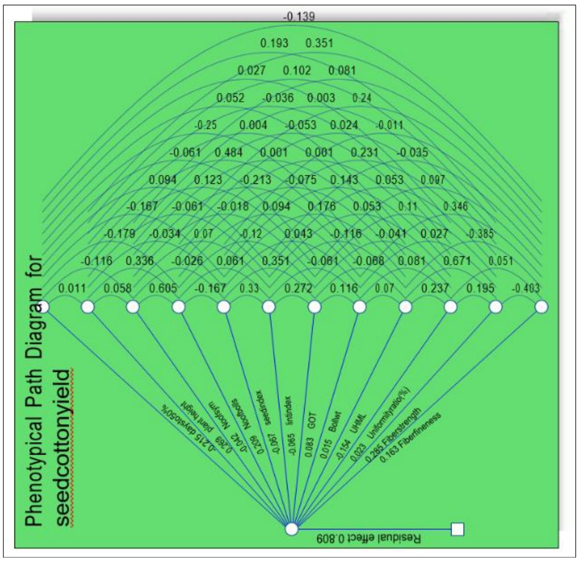

Fig 6: Phenotypical path diagram of seed cotton yield in American cotton

Results and Discussion

Correlation studies were conducted on 50 different cotton genotypes to investigate the interrelationships between various yield components at both genotypic (G) and phenotypic (P) levels. The results of the genotypic and phenotypic correlation coefficients for 13 characters are presented in Table 2. The characters at both genotypic and phenotypic level showed that number of bolls per plant, number of sympodia per plant, lint index, boll weight, plant height, Fiber Fineness and Fiber strength were positively correlated with seed cotton yield per plant. Days to 50% flowering, seed index, lint index, upper half mean length and uniformity ratio showed negative correlation with seed cotton yield per plant at both genotypic and phenotypic level as shown in Fig. 1 and 2. Similar results were reported by Ahsan *et al*., (2014) [4], Thiyagu *et al*., (2010) [33], Tulsi *et al*., (2012) [34], Adeel *et al*., (2014) [3], Sahito *et al*., (2016) [27], Shakeel *et al*., (2016) [30] and Gnanasekaran *et al*., (2020) [17]. Number of sympodia per plant showed positive and significant correlation with number of bolls per plant. Similar results were reported by Adeel *et al*., (2014) [3], Erande *et al*., (2014) [14], Shakeel *et al*., (2016) [30]. Seed index and lint index showed positive and significant correlation with each other and similar results obtained by Santoshkumar *et al*., (2014) [29]. The significant and positive correlation of boll weight with seed cotton yield and micronaire was obtained. The results are in accordance with the studies conducted by Baloch *et al*., (2015) [7], Jogender *et al*., (2023) [19]. Ginning percent exhibited positive and significant correlation with lint index and seed index. Ginning outturn is positively correlated with seed cotton yield per plant as observed by Farooq *et al*., (2014) [15]. This finding holds significant importance for breeders because it suggests that component breeding could be highly effective in this context. Selecting for improvements in all these traits has the potential to contribute to the development of high-yielding varieties of American cotton as in the shaded correlation matrix Fig. 3 and 4.

Path analysis between yield, yield contributing and fiber quality characters were carried out to find the direct and indirect effect from given component characters on seed cotton yield. Path coefficient analysis was worked out for thirteen different characters at both genotypic and phenotypic level. The results are presented in Table 3. Days to 50% flowering had shown negative direct effect (-0.215) on yield. Positive indirect effect on yield was exerted through boll weight (0.054), number of bolls per plant (0.038), seed index (0.036), number of sympodia per plant (0.025) and ginning outturn (0.013) as showed in Fig. 5 and Fig. 6. These results were in agreement with the results of Gulhane and Wadikar (2017) [6], Sainath *et al*., (2022) [28] and Shruti *et al*., (2020) [31]. Seed index and lint index exerted negative direct effect on seed cotton yield. similar results obtained by Latif *et al*., (2015) [22] and Dahiphale *et al*., (2015) [11]. Ginning percent exhibited positive direct effect on seed cotton yield per plant. Similar findings were reported by Erande *et al*., (2014) [14], Farooq *et al*., (2014) [15], Gulhane and Wadikar (2017) [6], Memon *et al*., (2017) [23] and Gauswamii (2021) [16]. The genotypic path analysis studies revealed that plant height (0.510), number of bolls per plant (0.404), uniformity ratio (0.339), ginning outturn (0.323), fiber strength (0.080) and lint index (0.029) exerted direct positive effect on seed cotton yield per plant. Whereas, days to 50 percent flowering, number of sympodia per plant, seed index, upper half mean length and micronnaire value exerted negative direct effect on seed cotton yield per plant. These results conform with the results reported by Erande *et al*., (2014) [14], Shruti *et al*., (2020) [31]. These findings underscore the multifaceted relationship between plant height and seed cotton yield, with various factors contributing to its positive impact on yield as observed in Fig. 5.

The path coefficient analysis conducted in our current study highlighted the significance of several traits, including the number of bolls per plant, ginning outturn, plant height, and lint index, in breeding for higher seed cotton yield per plant.

Table 2: Genotypic and phenotypic correlation coefficient analysis in fifty genotypes of Cotton

Characters		Days to 50% flowering	Plant Height (cm)	Number of Sympodia per plant	Number of Bolls per plant	Seed Index (g)	Lint Index (g)	Ginning Outturn (%)	Boll Weight (g)	UHML (mm)	Uniformity Ratio (%)	Fiber Strength (g/tex)	Fiber Fineness (µg/inch)	Seed Cotton Yield
Days to 50% flowering	G	1.000	0.0186	-0.161	-0.198*	-0.265**	0.096	-0.058	-0.281*	0.035	-0.065	0.212*	-0.164	-0.276*
	P	1.000	0.0114	-0.116	-0.178	-0.167	0.094	-0.061	-0.250*	0.052	0.027	0.193*	-0.138	-0.223*
Plant height (cm)	G		1.000	0.082	0.342**	-0.052	-0.084	0.136	0.555**	0.0027	0.064	0.114	0.369**	0.527**
	P		1.000	0.057	0.336**	0.033	-0.061	0.123	0.484**	0.004	-0.036	0.102	0.351**	0.443**
Number of Sympodia per plant	G			1.000	0.639**	-0.032	0.073	-0.026	-0.253*	-0.004	0.096	0.005	0.096	0.142
	P			1.000	0.605**	-0.026	0.070	-0.017	-0.213*	0.0006	-0.053	0.003	0.081	0.130
Number of bolls per plant	G				1.000	-0.193*	0.067	-0.116	0.098	-0.076	-0.063	0.033	0.260*	0.450**
	P				1.000	-0.167	0.062	-0.119	0.093	-0.075	0.001	0.024	0.240*	0.368**
Seed index (g)	G					1.000	0.515**	0.453**	-0.004	0.093	0.472**	0.179	-0.105	-0.091
	P					1.000	0.329**	0.351**	0.043	0.176	0.142	0.231*	-0.011	-0.026
Lint Index (g)	G						1.000	0.315**	-0.129	-0.176	0.028	0.032	-0.046	-0.086
	P						1.000	0.272**	-0.061	-0.116	0.052	0.053	-0.035	-0.064
Ginning Outturn (%)	G							1.000	0.131	-0.049	0.041	0.132	0.137	0.163
	P							1.000	0.116	-0.067	-0.041	0.110	0.096	0.122
Boll Weight (g)	G								1.000	0.047	0.035	-0.012	0.376**	0.301*
	P								1.000	0.070	0.081	0.027	0.346**	0.293*
UHML (mm)	G									1.0000	0.342**	0.641**	-0.556*	-0.064
	P									1.0000	0.236*	0.671**	-0.385**	-0.054
Uniformity Ratio (%)	G										1.0000	0.351**	0.366**	-0.024
	P										1.0000	0.194*	0.051	0.022
Fiber Strength	G											1.0000	-0.535**	0.117
	P											1.0000	-0.403**	0.102
Fiber Fineness	G												1.0000	0.325**
	P												1.0000	0.295**

*Significant at 5 per cent level, **Significant at 1 per cent level.

Table 3: Direct and Indirect effects phenotypic and Genotypic levels of yield components on seed yield in Cotton

Characters		Days to 50% flowering	Plant Height (cm)	Number of sympodia per plant	Number of bolls per plant	Seed Index (g)	Lint Index (g)	Ginning Outturn (%)	Boll Weight (g)	UHML (mm)	Uniformity Ratio (%)	Fiber Strength (g/tex)	Fiber Fineness (µg/inch)	Seed Cotton Yield
Days to 50% flowering	G	-0.427	-0.008	0.069	0.085	0.113	-0.041	0.025	0.120	-0.015	0.027	-0.091	0.070	-0.276**
	P	-0.215	-0.002	0.025	0.038	0.036	-0.020	0.013	0.054	-0.011	-0.006	-0.041	0.029	-0.223*
Plant height (cm)	G	0.009	0.510	0.042	0.174	-0.026	-0.043	0.069	0.283	0.001	0.033	0.058	0.188	0.527**
	P	0.003	0.269	0.015	0.090	-0.009	-0.016	0.033	0.130	0.001	-0.009	0.027	0.094	0.443**
Number of sympodia per plant	G	0.045	-0.023	-0.280	-0.179	0.009	-0.020	0.007	0.071	0.001	-0.027	-0.001	-0.027	0.142
	P	0.005	-0.002	-0.042	-0.025	0.001	-0.003	0.001	0.009	0.000	0.02	-0.000	-0.003	0.130
Number of bolls per plant	G	-0.080	0.138	0.258	0.404	-0.078	0.027	-0.047	0.039	-0.031	-0.025	0.013	0.105	0.450**
	P	-0.0373	0.070	0.126	0.209	-0.035	0.013	-0.025	0.019	-0.016	0.000	0.005	0.050	0.368**
Seed Index (g)	G	0.119	0.023	0.015	0.087	-0.450	-0.232	-0.204	0.002	-0.042	-0.212	-0.081	0.047	-0.091
	P	0.011	0.002	0.002	0.011	-0.067	-0.022	-0.024	-0.003	-0.012	-0.009	-0.016	0.001	-0.026
Lint Index (g)	G	0.003	-0.002	0.002	0.002	0.015	0.029	0.009	-0.004	-0.005	0.001	0.001	-0.001	-0.086
	P	-0.006	0.004	-0.005	-0.004	-0.022	-0.065	-0.018	0.004	0.008	-0.003	-0.003	0.002	-0.064
Ginning Outturn (%)	G	-0.019	0.044	-0.008	-0.037	0.146	0.102	0.323	0.042	-0.016	0.013	0.042	0.044	0.163
	P	-0.005	0.010	-0.002	-0.009	0.029	0.0226	0.083	0.009	-0.006	-0.003	0.009	0.008	0.122
Boll Weight (g)	G	0.041	-0.081	0.037	-0.014	0.001	0.019	-0.019	-0.146	-0.007	-0.005	0.002	-0.055	0.300**
	P	-0.004	0.007	-0.003	0.001	0.001	-0.001	0.001	0.015	0.001	0.001	0.000	0.005	0.293**
UHML (mm)	G	-0.009	-0.001	0.001	0.021	-0.025	0.048	0.013	-0.013	-0.275	-0.094	-0.176	0.153	-0.064
	P	-0.008	-0.001	-0.000	0.012	-0.027	0.018	0.010	-0.011	-0.154	-0.036	-0.103	0.059	-0.054
Uniformity Ratio (%)	G	-0.022	0.022	0.033	-0.021	0.160	0.009	0.014	0.012	0.116	0.339	0.119	0.124	-0.024
	P	0.001	-0.001	-0.001	0.000	0.003	0.001	-0.001	0.002	0.005	0.023	0.004	0.001	0.022
Fiber Strength	G	0.017	0.009	0.0004	0.003	0.014	0.003	0.012	-0.001	0.051	0.028	0.080	-0.043	0.117
	P	0.055	0.029	0.001	0.007	0.066	0.015	0.031	0.007	0.192	0.056	0.285	-0.115	0.102
Fiber Fineness	G	0.046	-0.104	-0.027	-0.073	0.029	0.013	-0.039	-0.106	0.156	-0.103	0.150	-0.281	0.325**
	P	-0.022	0.057	0.013	0.039	-0.002	-0.006	0.016	0.056	-0.063	0.008	-0.066	0.163	0.295**

R=0.50 (at genotypic level), Residual effect=0.70, R=0.34 (at phenotypic level), Residual effect=0.80
*Significant at 5 per cent level, **Significant at 1 per cent level.

Conclusion

The investigations conducted in this study unveiled that several traits, including the number of bolls per plant, plant height, boll weight, number of sympodia, ginning percent, lint index, and fiber fineness, stood out as the most crucial characteristics for the effective selection of superior genotypes of American cotton. These traits exhibited high heritability, significant positive correlations, and substantial direct effects on seed cotton yield. Consequently, they should be prioritized in the selection process when aiming to breed high-performing American cotton varieties.

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