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Genetic variability exploration in upland cotton (*Gossypium hirsutum* L.) for yield and fiber traits

Hardik H Patel, Kalpesh V Patel, Vipul L Suthar, Rahul J Parmar and Sunil K Patel

Hardik H Patel
Department of Genetics and Plant Breeding, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Kalpesh V Patel
Medicinal and Aromatic Plants Research Station, Anand Agricultural University, Anand, Gujarat, India

Vipul L Suthar
Department of Genetics and Plant Breeding, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Rahul J Parmar
Department of Genetics and Plant Breeding, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Sunil K Patel
Department of Genetics and Plant Breeding, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Corresponding Author:
Hardik H Patel
Department of Genetics and Plant Breeding, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Abstract
This experiment aimed to investigate genetic variability among the all genotypes along with heritability presence, genetic advance per cent over mean, correlation studies and path coefficient carried out for 17 different characters in 16 genotypes, including sixty-four F_1 hybrids, and one check G. Cot. Hy. 18 of upland cotton (*Gossypium hirsutum* L.). The trail was demonstrated during the *Kharif* season of 2022 at the Regional Research Station (RRS), Anand Agricultural University, India. Variability studies revealed high phenotypic coefficient of variation (PCV) and moderate genotypic coefficient of variation (GCV) for the number of bolls per plant, lint yield per plant and seed cotton yield per plant. Additionally, the number of monopodia per plant exhibited a high estimate of both PCV and GCV. Heritability analysis showed high heritability for various traits, including days to 50% flowering, days to 50% boll bursting, plant height, monopodia per plant, sympodia per plant, number of bolls per plant, boll weight, lint yield per plant, seed cotton yield, seed index, fiber strength, fiber fineness, and seed oil content. Moreover, days to 50% flowering, plant height, number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight, lint yield per plant, seed cotton yield, fiber fineness, and seed oil content demonstrated both high heritability and significant genetic advance as per cent over the mean. This stipulate significant attributing part of additive gene action in the heredity of these characteristics. During the correlation study, it was found that seed cotton yield per plant showed noteworthy positive correlations with several traits: the number of sympodia per plant (0.29), the number of bolls per plant (0.77), fiber length (0.26), uniformity index (0.37), and lint yield per plant (0.95). Path analysis revealed that seed index and ginning outturn had the highest positive and direct effects on seed cotton yield per plant.

Keywords: Cotton, patents, hybrids, correlation, heritability, path analysis, seed cotton yield, variability

Introduction
Cotton holds significant economic importance, and India's textile industry contributing a major domination in the economy. The fluctuations in cotton production can pose a substantial threat to the economic stability of our market channels. Therefore, achieving a consistently sufficient cotton production has become crucial. Moreover, maximizing the yield per unit area is essential since we cannot afford to allocate more land for cotton cultivation at the expense of other crops. For a cotton breeder, the primary objective is to develop high-yielding varieties by utilizing available genetic resources through selection and breeding processes. During the correlation study, it was found that seed cotton yield per plant showed noteworthy positive correlations with several traits: the number of sympodia per plant (0.29), the number of bolls per plant (0.77), fiber length (0.26), uniformity index (0.37), and lint yield per plant (0.95). Due to the complex nature of their interaction, it becomes challenging to select plants from the breeding population that exhibit a harmonious combination of desirable traits. Hence, in order to discover potential cotton genotypes, the breeder needs to conduct a comprehensive examination of the breeding material, aiming to comprehend the specific relationships and strengths of correlations within the characters *viz*, seed cotton yield, plant height, number of bolls, boll weight, and ginning outturn, especially some specific environmental circumstances (Naveed *et al*., 2004) [14]. In their pursuit of enhancing crop productivity, plant breeders continuously work towards developing more dependable and relatively simpler methodologies. The correlation coefficient serves as a vital breeding parameter, indicating the degree of association between two traits. If a strong and well-established relationship exists between two traits, a highly heritable character could potentially be used as an indirect selection criterion to improve a low heritable trait, such as yield. Moreover, the effectiveness of breeding activity greatly hinges on the presence of abundant genetic variability and heritability of a trait that

can be readily selected for. Understanding the correlations between key traits can aid in interpreting research outcomes and serve as a foundation for designing more efficient and effective breeding programs. Seed cotton yield, being a complex characteristic, it relies various component traits. These traits exhibit diverse types of associations with each other. Understanding the interrelationships separating seed cotton yield and yield ascribing traits becomes essential for making simultaneous improvements in these characters. Path coefficient analysis allows us to explore the closest contributions of various traits, both direct effect and indirect effects and their interconnections and linkages. By conducting path coefficient analysis, we can gain valuable insights into the intricate relationships between the component traits and their impacts on seed cotton yield.

The heritability, which represents the genetic variance passed on to the offspring, plays a crucial role in enhancing any quantitative trait (Nizamani *et al*., 2017) [16]. Despite numerous studies conducted by various researchers on genetic variability and heritability estimates in wheat, variations in their findings persist. These variations may arise from differences in the genetic materials used, methodologies employed, and environmental conditions in which the breeding materials were evaluated (Baloch *et al*., 2011) [4]. In this study, we also sought to estimate heritability and correlation coefficients among the parents and F_1 hybrids of intra-hirsutum crosses, focusing on yield-contributing characters in cotton.

Materials and Methods

Field layout and procedure

The experiment was performed at the Regional Research Station (RRS), Anand Agricultural University (AAU), Anand, Gujarat, India, in the *Kharif* season of 2021. Throughout the cropping period, the average maximum temperature was recorded at 33.9˚C, whereas, average minimum temperature was 18.2˚C. The area experienced an average rainfall of 3.04 mm, distributed over 24 rainy days. The location coordinates of the experimental site are approximately 22˚ 35' N and 72˚ 55' E for latitude and longitude, respectively, with an elevation of 45.10 m above mean sea level (MSL). The soil type is of sandy loam type, specifically classified as *Goradu* soil, with a pH value of 8.2.

The research material consists of 64 intra-hirsutum hybrids, along with their parents as well as a control check, G. Cot. Hy. 18. The F_1 hybrids were created through crosses between eight female parents: AHC 50, AHC 28, AHC 29, AHC 31, AHC 33, GSHV 206, GSHV 209, and G. Cot. 20, and eight male testers: AHC 23, AHC 35, AHC 36, AHC 37, AHC 42, ACH 1501, GSHV 208, and GSHV 239, following a Line × Tester mating approach. This resulted in the development of eighty-one genotypes during the *Kharif* season of 2022. Three replications of the experimental materials were grown using a randomized block design (RBD). The crop was raised in double rows, each 4.5 meters long, with 120 cm and 45 cm inter row spacing and inter plants, respectively. To ensure healthy crop stand, recommended proper agronomic practices and appropriate integrated plant protection measures were diligently implemented all through the evaluation time.

Data analysis

Data was gathered from five plants that were chosen at random in each and every entry, and seventeen various traits were recorded, including days to 50% flowering, days to 50% boll bursting, plant height (cm), number of monopodial branches per plant, number of sympodial branches per plant, number of bolls per plant, boll weight (g), lint yield per plant (g), seed cotton yield per plant (g), lint index (g), seed index (g), ginning outturn (%), fibre strength (g/tex), fiber length (mm), fibre fineness (µg/inch), uniformity index (%) and seed oil content (%). To identify the fiber quality attributes, the seed cotton from the studied plants was mixed, ginned, and analysed in the lint that resulted. These traits were assessed using a Compact HVI at the Central Institute for Research on Cotton Technology, Surat, Gujarat. Additionally, the percentage of oil content in cotton seeds was calculated for each sample using a Near Infrared Resonance (NIR) machine. The collected data was used to calculate the averages for each of the observed parameters.

Calculation

The observed parameters were analysed by R-Statistical Software (RStudio) v 2023.03. Further, for calculating the means of various parameters subsequently, an Analysis of Variance (ANOVA), following method was carried out by Johnson *et al*. (1955) [11]. Using a formula provided by Falconer (1981) [9], the genotypic and phenotypic coefficients of variation were determined. To calculate the heritability (h^2) in the broad sense, Allard's formula (1960) was applied. Estimation of genetic advance was carried out using formula proposed by Burton (1953) [5] based on the heritability. Correlation coefficients at both phenotypic and genotypic levels were computed following the procedure described by Al-Jibouri *et al*. (1958) [2]. Additionally, path analysis was conducted using the approach proposed by Dewey and Lu (1959) [6].

Results and Discussion

Variability analysis

The effectiveness of a breeding program relies primarily on the genetic diversity present within the segregating population. When aiming to enhance the population, accurately assessing the level of genetic variability becomes crucial for improving specific traits. The magnitude of variation itself may not be the key factor, but rather the degree of heritable deviation is what matters in accomplish progress through selection programs. A higher heritability simplifies the selection procedure and leads to a greater response to both genotypic and phenotypic selection.

Table 1 presents the genetic parameters for all seventeen characters, including PCV and GCV. Notably, the character monopodia per plant exhibited a significant level of variability, with a high estimate of 27.04% for PCV and 25.05% for GCV. Fig. 1 shows the graphical representation of GCV and PCV over the various characters.

Significant PCV with moderate GCV were observed for various traits in the study. Traits like the number of bolls per plant (PCV: 24.66%, GCV: 19.72%), lint yield per plant (PCV: 21.81%, GCV: 18.81%) and seed cotton yield per plant (PCV: 22.31%, GCV: 19.23%) revealed high PCV and moderate GCV values. On the other hand, traits like days to 50% flowering (PCV: 10.72%, GCV: 10.49%), plant height (PCV: 14.62%, GCV: 14.47%), number of sympodia per plant (PCV: 15.28%, GCV: 13.31%), boll weight (PCV: 18.61%, GCV: 16.42%), lint index (PCV: 16.38%, GCV: 12.49%), fiber fineness (PCV: 14.76%, GCV: 12.35%), and seed oil content (PCV: 15.08%, GCV: 14.45%) showed moderate estimates of PCV and GCV. Traits such as days to 50% boll bursting (PCV: 8.13%, GCV: 7.34%), ginning outturn (PCV: 7.15%, GCV: 5.15%), fiber strength (PCV: 5.12%, GCV: 4.79%), fiber length (PCV: 5.12%, GCV: 3.67%), and uniformity index (PCV: 3.58%, GCV: 1.97%) displayed low PCV and GCV values, indicating a strong interference of environmental factors on the above traits. The findings suggested that environmental factors played significant role in shaping these traits, making selection for improvement potentially misleading. These findings are consistent with earlier investigations carried out by Kulkarni et al. (2011) [13], Pujer *et al.* (2014) [18, 19], Sunayana *et al.* (2017) [21, 22], and Gnanasekaran *et al.* (2018) [10].

Table 1: Components of variance for various yield traits and fibre quality traits in the parents and their hybrids

Characters	Variance		PCV	GCV
	σ^2_p	σ^2_g		
DFF	42.00	40.18	10.72	10.49
FBB	73.49	59.97	8.13	7.34
PH	815.42	798.10	14.62	14.47
MPP	1.51	1.29	27.04	25.05
SPP	15.39	11.67	15.28	13.31
BPP	123.98	79.31	24.66	19.72
BW	0.97	0.76	18.61	16.42
LYPP	446.23	310.16	21.81	18.18
SCY	3464.85	2575.73	22.31	19.23
LI	1.09	0.64	16.38	12.49
SI	1.63	1.09	11.59	9.62
GOT	6.93	3.60	7.15	5.15
FS	1.92	1.68	5.12	4.79
FL	1.93	0.99	5.12	3.67
FF	0.46	0.32	14.76	12.35
UI	9.12	2.76	3.58	1.97
SOC	9.12	8.37	15.08	14.45

Heritability

Considerable heritability values were observed for various characters in the study as shown in Table 2 and Fig. 2. Traits such as days to 50% flowering (95.65%), days to 50% boll bursting (81.61%), plant height (97.88%), number of monopodial branches per plant (85.85%), number of sympodial branches per plant (75.87%), number of bolls per plant (63.97%), boll weight (77.84%), lint yield per plant (69.51%), seed cotton yield per plant (74.34%), seed index (67.66%), fibre strength (87.53%), fibre fineness (70.02%) and seed oil content (91.89%) demonstrated high heritability values. This suggests that additive gene action primarily influences above traits and, consequently, can be effectively targeted for selection and improvement in future breeding programs. On the other hand, traits like lint index, ginning outturn, fiber length and fiber fineness exhibited moderate estimates of heritability, suggesting a more balanced influence of both genetic and environmental factors on their expression.

Table 2: Components of variance (h^2 and GAM) for various yield traits and fibre quality traits in the parents and their hybrids

Characters	Heritability	GAM
DFF	95.65	21.12
FBB	81.61	13.66
PH	97.88	29.48
MPP	85.85	47.82
SPP	75.87	23.89
BPP	63.97	32.49
BW	77.84	29.84
LYPP	69.51	31.23
SCY	74.34	34.16
LI	58.12	19.61
SI	67.66	16.29
GOT	51.94	7.65
FS	87.53	9.23
FL	51.4	5.42
FF	70.02	21.29
UI	30.22	2.23
SOC	91.89	28.54

Heritability estimates alone are less helpful than heritability estimates along with genetic advances in projecting yield under phenotypic selection, according to earlier research of Johnson *et al*. (1955) [11] and Swarup and Chaugale (1962) [23]. When heritability is highly influenced by non-additive gene effects, the expected genetic advance tends to be low. Conversely, if a significant additive gene effect is present, a higher genetic advance is anticipated (Panse, 1957) [17]. In this research, notable heritability values were observed, accompanied by significant genetic advances as a percentage of the mean, for various traits *viz.*, days to 50% flowering, plant height, number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight, lint yield per plant, seed cotton yield per plant, fiber fineness, and seed oil content.

These findings imply that inheritance of above traits is influenced to a great extent by additive gene action, making them suitable for direct phenotypic selection to facilitate improvement.

Conversely, the trait fiber strength displayed high heritability (87.53%) but a low estimate of genetic advance (9.23%), which suggests the predominance of non-additive gene action influencing this particular trait. For this particular trait, heterosis breeding may be a more rewarding approach. By considering both heritability estimates and genetic advance, breeders can make more informed decisions in selecting appropriate breeding strategies for different traits, thereby enhancing the efficiency of crop improvement programs.

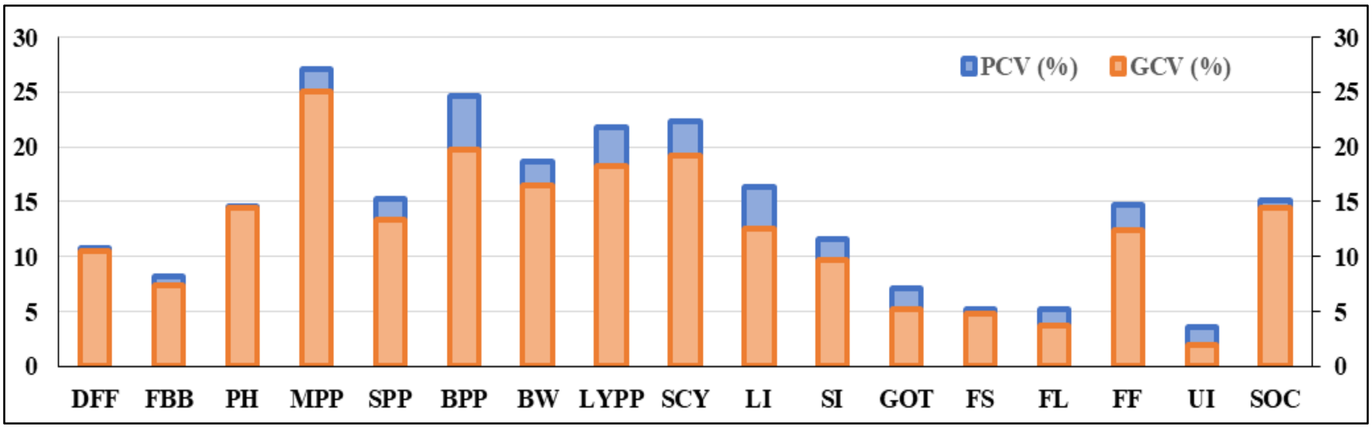

Fig 1: Genotypic and phenotypic coefficient of variation of various traits of cotton

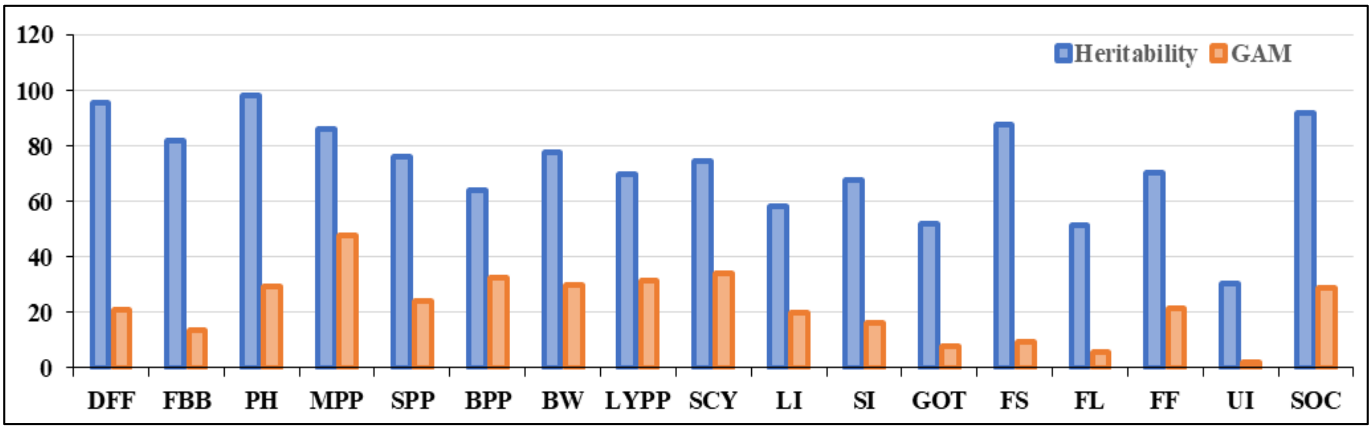

Fig 2: Heritability and genetic advance as per cent of mean of various traits of cotton

Correlation

Evaluating the correlations of yield with its contributing traits is of important significance in the choice of plants. Table 3 illustrates the GCV and PCV of seed cotton yield with its components. The correlation analysis revealed that seed cotton yield per plant demonstrated significant and positive associations with five characters: number of sympodia per plant (0.29), number of bolls per plant (0.77), fiber length (0.26), uniformity index (0.37) and lint yield per plant (0.95). Therefore, selecting genotypes with favourable traits in these areas will contribute to higher seed cotton yield per plant. However, there were strong negative associations between seed cotton production and plant height, the number of monopodial branches per plant, the days to 50% boll bursting, and ginning outturn. The strong association between seed cotton yield and these traits can be advantageously utilized in the selection program to cultivate high-yielding genotypes. Traits such as boll weight, fiber fineness, fiber strength, seed oil content, seed index and lint index exhibited non-significant associations with seed cotton yield. Despite their lack of direct correlation with yield, these traits might still hold valuable contributions in other aspects of plant development and quality improvement.

The intercorrelation among traits holds a crucial role in the selection process. The study revealed positive and statistically significant intercorrelations among the quantitative yield-contributing traits, specifically, the number of sympodial branches per plant, number of bolls per plant, boll weight, and lint yield per plant. Plant height showed notable and meaningful genotypic correlations with the number of monopodial branches per plant, number of sympodial branches per plant, and boll weight. Additionally, there were positive and substantial genotypic correlation between the number of monopodial branches per plant and the fiber fineness and uniformity indices. Similarly, the number of sympodia per plant demonstrated positive significant genotypic correlations with the number of bolls per plant, boll weight, uniformity index, and lint yield per plant. Moreover, the number of bolls per plant exhibited positive significant genotypic correlations with both uniformity index and lint yield per plant. The trait of boll weight displayed significant positive genotypic correlations with fiber length, uniformity index, seed index and lint index, designating the possibility of simultaneously enhancing these traits through breeding efforts. Therefore, selecting based on plant height, number of sympodial branches per plant and number of bolls per plant, in conjunction with boll weight and lint yield per plant, could lead to a significant breakthrough in enhancing cotton yields. Similar results were reported in studies carried out by Rao and Gopinath (2013) [20] and Kalpande *et al*. (2008) [12].

Path Analysis

The study of path coefficients provides valuable insights for breeders to focus on variables that have a substantial direct effect on seed cotton yield. Figure 3 shows the direction and effects of. several traits on seed cotton yield per plant. In this study, the genotypic correlation coefficient of seed cotton yield and several qualitative and quantitative traits was subjected to further analysis, distinguishing between direct and indirect effects (as shown in Table 4). The results indicated that the traits seed index and ginning outturn demonstrated the highest positive direct effects (>1) on the seed cotton yield per plant. Interestingly, the correlation between above traits and seed cotton yield per plant was found to be non-significant. Following closely were lint yield per plant and uniformity index, showing high positive and direct effects within the range of 0.03 to 0.99. Boll weight displayed a moderate positive direct effect (0.2-0.29) on seed cotton yield per plant. Trait days.to 50% flowering showed a low positive and direct effect (0.10-0.19) on seed cotton yield. Traits plant height, the number of monopodia per plant, the number of sympodia per plant, the lint index, the fiber strength, length and fineness, as well as the seed oil content, all had a negligibly negative direct impact on the yield of seed cotton per plant. Furthermore, days to 50% boll bursting and number of bolls per plant displayed negligible positive and direct effects on seed cotton yield per plant. Considering these results, it is advisable to adopt a direct selection approach that certainly targets traits such as seed index and ginning outturn to achieve significant yield improvements in cotton breeding programs. Comparable findings were documented by Dinakaran *et al*. (2012) [7] concerning lint yield per plant, Sunayan *et al*. (2017) [21, 22] regarding lint index, and Rao and Gopinath (2013) [20] for fiber length, fiber strength, fiber fineness and uniformity ratio. In the study, the indirect effects of certain traits on seed cotton yield were observed. The number of bolls per plant displayed a positive indirect effect on seed cotton yield through lint yield per plant, lint index, fiber fineness, and uniformity index.

Table 3: Estimation of phenotypic (lower diagonal) and genotypic (upper diagonal) correlation coefficient for yield and its component traits

Char.	DFF	FBB	PH	MPP	SPP	BPP	BW	LYPP	LI	SI	GOT	FS	FL	FF	UI	SOC	SCY
DFF	1	0.59**	0.32**	0.24 *	0.04	-0.28 *	0.25*	-0.23 *	0.05	0.07	0.01	0.22 *	0.04	0.22	-0.04	0.08	-0.22 *
FBB	0.52 **	1	0.19	0.09	-0.13	-0.32 **	0.1	-0.29 **	0.12	0.03	0.16	-0.09	0.02	-0.06	-0.41 **	-0.02	-0.32 **
PH	0.31 **	0.17 **	1	0.27 *	0.35 **	-0.25 *	0.23*	-0.31 **	0.07	-0.02	0.11	-0.01	0.17	-0.07	0.24 *	-0.09	-0.32 **
MPP	0.22 **	0.08	0.24 **	1	0.08	-0.29 **	0.12	-0.28 *	-0.01	0.08	-0.13	0.02	0.04	0.29 *	0.31 **	0.07	-0.22 *
SPP	0.04	-0.11	0.31 **	0.08	1	0.32 **	0.27*	0.24 *	-0.02	0.11	-0.18	0.05	0.18	-0.04	0.66 **	-0.04	0.29 *
BPP	-0.22 **	-0.23 **	-0.19 **	-0.22 **	0.18 **	1	-0.27*	0.77 **	-0.19	-0.15	-0.12	-0.04	0.06	-0.18	0.29 **	0.01	0.77 **
BW	0.22 **	0.09	0.20 **	0.11	0.21 **	-0.32 **	1	0.18	0.23 *	0.37 **	-0.1	0.12	0.35**	0.13	0.23 *	-0.21	0.21
LYPP	-0.19 **	-0.21 **	-0.26 **	-0.19 **	0.17 **	0.71 **	0.12	1	0.15 *	0.09	0.13	0.03	0.13 *	-0.08	0.15 *	-0.01	0.95 **
LI	0.04	0.13 *	0.05	0.01	-0.05	-0.1	0.18 **	0.12	1	0.73 **	0.69 **	0.15 *	0.25 **	-0.15 *	0.05	0.13	-0.07
SI	0.07	0.06	-0.02	0.09	0.06	-0.12	0.27 **	0.15	0.77 **	1	0.03	0.28 **	0.29 **	-0.1	0.07	0.25 *	0.15
GOT	-0.01	0.12	0.07	-0.08	-0.14 *	-0.04	-0.02	-0.01	0.63 **	-0.01	1	-0.04	0.03	-0.1	-0.16	-0.11	-0.29 **
FS	0.20 **	-0.08	-0.01	0.04	0.04	-0.01	0.1	0.04	0.24 *	0.37 **	-0.05	1	0.53**	-0.23 **	0.45 **	0.27 *	0.06
FL	0.03	0.02	0.11	0.01	0.04	0.07	0.18 **	0.26 *	0.38 **	0.46 **	0.04	0.37 **	1	-0.33 **	0.43 **	0.14	0.26 *
FF	0.17 **	-0.06	-0.05	0.18 **	-0.05	-0.11	0.14 *	-0.12	-0.2	-0.15	-0.09	-0.29 **	-0.64 **	1	-0.01	-0.17	-0.09
UI	-0.01	-0.18 **	0.14 *	0.12	0.27 **	0.14 *	0.08	0.33 **	0.16	0.31 **	-0.02	0.19 **	0.16 *	-0.01	1	0.19	0.37 **
SCO	0.08	-0.02	-0.08	0.06	-0.03	-0.01	-0.19 **	-0.01	0.09	0.19 **	-0.08	0.25 **	0.11	-0.15 *	0.08	1	0.03
SCY	-0.18 **	-0.25 **	-0.27 **	-0.16 *	0.22 **	0.71 **	0.14 *	0.94 **	-0.09	0.09	-0.22 **	0.05	0.12	-0.05	0.15 *	0.01	1

*, ** Significant at 0.05 and 0.01 levels of probability, respectively

(DFF – Days to 50% flowering, FBB – Days to 50% boll bursting, PH – Plant height, MPP – Monopodia per plant, SPP – Sympodia per plant, BPP – Bolls per plant, BW – Boll weight, LYPP – Lint yield per plant, LI – Lint index, SI – Seed index, GOT – Ginning outturn, FS – Fiber strength, FL – Fiber length, FF – Fiber fineness, UI – Uniformity index, SCO – Seed oil content, SCY – Seed cotton yield per plant)

Table 4: Genotypic path coefficient analysis showing direct and indirect effects of different characters on seed cotton yield per plant

	DFF	FBB	PH	MPP	SPP	BPP	BW	LYPP	LI	SI	GOT	FS	FL	FF	UI	SOC	SCY
DFF	0.160	0.045	-0.018	-0.017	-0.014	-0.019	0.054	-0.182	-0.261	0.259	0.016	-0.078	-0.015	-0.117	-0.027	-0.006	-0.220 *
FBB	0.095	0.076	-0.011	-0.006	0.052	-0.022	0.023	-0.225	-0.610	0.112	0.440	0.030	-0.007	0.033	-0.300	0.001	-0.320 **
PH	0.051	0.014	-0.056	-0.019	-0.141	-0.017	0.050	-0.248	-0.349	-0.081	0.314	0.005	-0.069	0.037	0.180	0.007	-0.323 **
MPP	0.038	0.007	-0.015	-0.070	-0.034	-0.020	0.027	-0.216	0.026	0.318	-0.357	-0.006	-0.017	-0.125	0.227	-0.005	-0.221 *
SPP	0.006	-0.010	-0.020	-0.006	-0.399	0.022	0.059	0.185	0.113	0.432	-0.515	-0.019	-0.073	0.024	0.482	0.003	0.284 *
BPP	-0.044	-0.025	0.014	0.020	-0.125	0.070	-0.060	0.604	0.955	-0.593	-0.345	0.012	-0.024	0.101	0.211	0.000	0.771 **
BW	0.039	0.008	-0.013	-0.009	-0.106	-0.019	0.221	0.138	-1.133	1.422	-0.268	-0.042	-0.144	-0.073	0.170	0.015	0.207
LYPP	-0.037	-0.022	0.018	0.019	-0.094	0.054	0.039	0.785	-0.576	0.582	-0.003	-0.015	-0.106	0.065	0.245	0.000	-0.297 **
LI	0.008	0.009	-0.004	0.000	0.009	-0.013	0.050	0.091	-4.984	3.006	1.783	-0.086	-0.157	0.111	0.115	-0.009	-0.085
SI	0.011	0.002	0.001	-0.006	-0.044	-0.011	0.081	0.117	-3.850	3.892	-0.012	-0.130	-0.193	0.084	0.226	-0.019	0.060
GOT	0.001	0.012	-0.006	0.009	0.072	-0.008	-0.021	-0.001	-3.131	-0.017	2.838	0.015	-0.011	0.056	-0.115	0.008	0.256 *
FS	0.035	-0.007	0.001	-0.001	-0.022	-0.002	0.026	0.034	-1.217	1.438	-0.122	-0.353	-0.219	0.157	0.330	-0.020	0.365 **
FL	0.006	0.001	-0.009	-0.003	-0.070	0.004	0.077	0.200	-1.882	1.804	0.073	-0.185	-0.416	0.352	0.315	-0.010	0.150
FF	0.034	-0.005	0.004	-0.016	0.018	-0.013	0.030	-0.093	1.013	-0.601	-0.291	0.101	0.268	-0.547	-0.001	0.013	-0.071
UI	-0.006	-0.031	-0.014	-0.022	-0.262	0.020	0.051	0.261	-0.775	1.195	-0.442	-0.158	-0.178	0.001	0.737	-0.014	0.953 **
SOC	0.013	-0.001	0.005	-0.005	0.017	0.000	-0.046	-0.001	-0.621	0.975	-0.317	-0.096	-0.057	0.095	0.139	-0.075	0.025

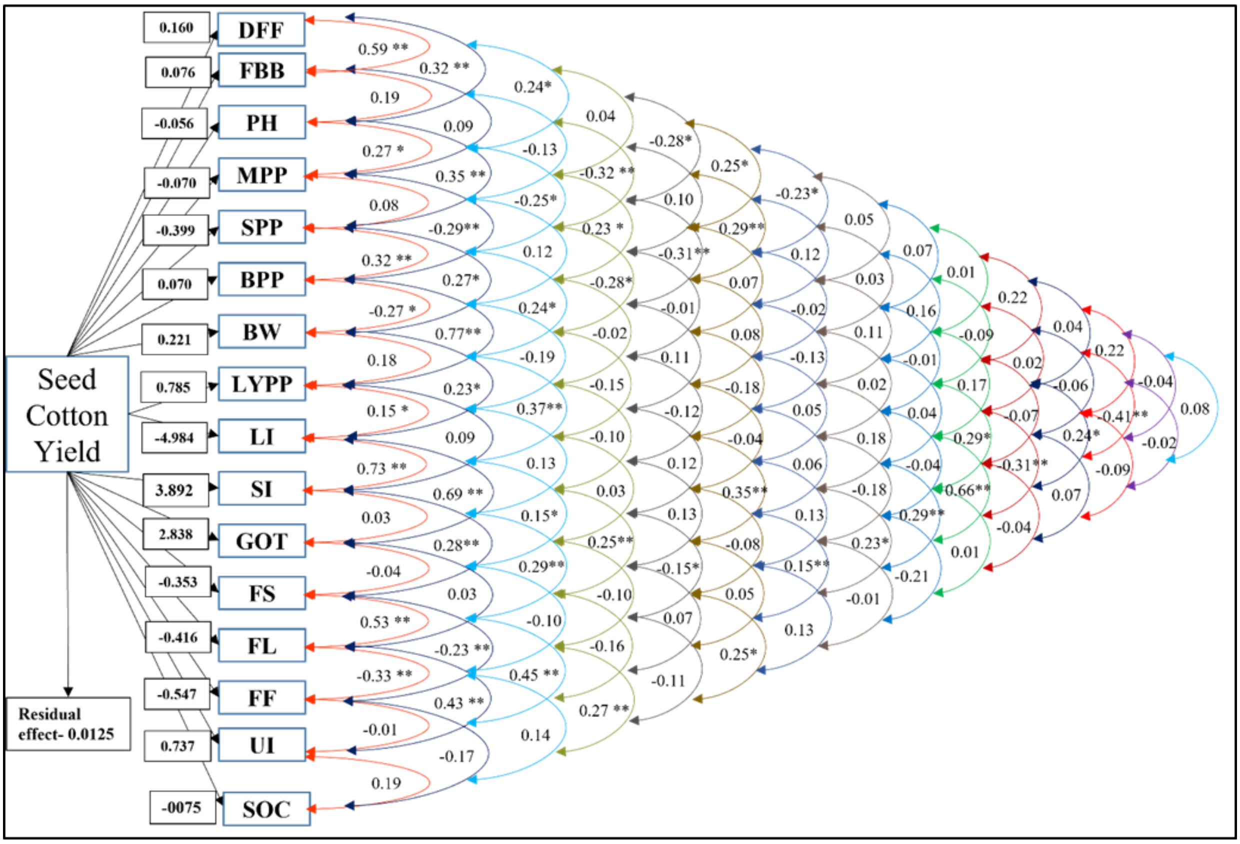

Fig 3: Path diagram showing direct and indirect effect of various traits on seed cotton yield

However, it had a negative and indirect effect through the number of sympodia per plant, seed index, and ginning outturn Alternatively, boll weight exhibited a positive and indirect effect on yield through lint yield per plant, seed index, and uniformity index, but a negative and indirect effect through the number of sympodia per plant, lint index, ginning outturn, fiber length, and fiber fineness. Character seed index displayed a positive and indirect effect on seed cotton yield *via* lint yield per plant and uniformity index, while its negative indirect effect was observed through lint index, fiber strength, and fiber length. These findings highlight the complex interplay of traits and their impact on seed cotton yield, providing valuable insights for breeding programs aiming to enhance cotton yield. Erande *et al.* (2014) [8], Pujer *et al.* (2014) [18, 19], Nikhil *et al.* (2018) [15] reported positive and negligible direct effect of character number of bolls per plant on seed cotton yield per plant.

Conclusion

The trait monopodia per plant, genotypes displayed higher values of GCV and PCV, implying that there is more potential for development in this trait by using phenotypic and genotypic selection in the right way. As a whole, the study found that plant height, days to 50% flowering, seed oil content, fiber strength, monopodia per plant, days to 50% bursting, boll weight, sympodia per plant, seed cotton yield per plant, fiber fineness, lint yield per plant, seed index, and number of bolls per plant all had high heritability values. In particular, traits like days until 50% flowering, plant height, number of monopodia and sympodia per plant, number of bolls and boll weight per plant, yield of seed cotton, fiber fineness, and seed oil content showed high heritability along with high genetic advance over the mean, indicating a predominance of gene action that is additive in the generational transmission of these traits. As a promising method to achieve significant improvements in cotton yields, we suggest a simultaneous selection technique that focuses on traits like plant height, number of sympodial branches per plant, number of bolls per plant, coupled with boll weight and lint yield per plant. Furthermore, delaying the selection of new or advanced generations is advised for the best outcomes.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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