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Association Analysis for Economic Traits in Upland Cotton (*Gossypium hirsutum* L.)

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ABSTRACT

Background: *Gossypium hirsutum,* the most widely cultivated crop in the world has concurrent importance for both fibre quality and yield. Polygenes regulate cotton output and a variety of factors affect the characteristic. As a result, it is essential to have thorough knowledge of the relationships between different component traits and fibre quality. Thus, the aim of the study was framed to know about the correlation along with cause-and-effect relationship among the economic traits.

Mathod: Eight parents and 56 hybrids made up the experimental sample for our study, which were evaluated for 18 economically significant traits. The study was conducted at Department of Cotton, Tamil Nadu Agricultural University, Coimbatore, in 2021-2022.

Results: Analysis of variance was highly significant for all the traits studied. The result of correlation revealed that the traits *viz.,* number of bolls per plant, boll weight, number of seeds per boll, upper half mean length and fibre strength had a high magnitude of positive correlation with seed cotton yield at both genotypic and phenotypic levels. Path analysis represented the direct effects of upper half mean length, uniformity index, number of bolls per plant, number of seeds per boll and fibre strength on seed cotton yield. Hence, these traits can be used as selection criteria for yield improvement in cotton.

Keywords: Correlation, Path analysis, Upland cotton.

INTRODUCTION

Gossypium hirsutum L. or upland cotton is the most predominantly cultivated crop species globally (Giri *et al.* 2020). In India, it plays a dominant role in the industrial and agricultural sectors economically. It accounts for nearly 33% of the total foreign exchange of India. India ranks first in acreage occupying 37% of the world area under cotton cultivation and the largest producer accounting for 22% of world cotton production (Cotton Corporation of India, 2022). Around 40-50 million people in India earn their livelihood from cotton cultivation (Reddy *et al.* 2019 and Giri *et al.* 2021). There is greater emphasis on producing cotton of superior quality due to the modernization of the spinning industry, yet the interest of farmers relies on high yield (Srinivas and Bhadru, 2015). Thus, the primary cotton breeding objective relies on the development of high-yielding varieties with improved fibre quality. Cotton yield is determined by several intricate component traits. Several cotton breeders select high-yielding cultivars based on the genetic relationship of yield with its attributing traits (Bechere *et al.* 2014). Since cotton yield is controlled by polygenes, many factors influence the trait. Hence, thorough knowledge of association among various component traits with seed cotton yield is necessary. Phenotypic correlation, estimates the extent of change that occur in one trait due to other traits while genotypic correlation reveals the inherent association between the genes controlling the traits (Gnanasekaran *et al.* 2020). Practically, the simple correlation will not exhibit the cause-and-effect inter-relationship of economic traits for effective selection. Hence, for decisive evaluation, path analysis should be done to measure the direct and indirect effects of the component traits. Thus, the present study aimed to quantify the inter-relationship among yield and quality traits and also to identify the direct and indirect effects of these component traits on yield.

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MATERIALS AND METHODS

The research was conducted during 2021-2022 at the Department of Cotton, Tamil Nadu Agricultural University, Coimbatore. The experimental material (Fig 1) comprises eight parents and 56 hybrids obtained by diallel mating including direct and reciprocal crosses. These parents were raised in crossing block during February 2021 and crossed in a diallel fashion to obtain 56 hybrids. During August 2021, the hybrids along with their parents were raised in a randomized complete block design with two replications. The row-to-row spacing and plant-plant spacing followed were 90 cm and 45 cm, respectively. All the recommended packages of agronomic practices were followed till harvest. Five random plants from each cross in each replication were tagged and data for component traits include plant height (cm), days to fifty per cent flowering (number of days), days to first boll bursting (number of days), number of monopodia per plant, number of sympodia per plant, number of bolls per plant, number of locules per boll, boll weight (g), number of seeds per boll, seed cotton yield per plant (g), seed index (g), lint index (g), ginning out turn (%), upper half mean length (distance spanned by a specified percentage of fibre in a specimen being tested and where the initial starting point of the scanning in the test is considered 100%, expressed in mm), fibre strength (g/tex), fibre fineness or micronaire (µg/inch), uniformity index and elongation percentage (%) were recorded All statistical analyses were performed using R studio version 1.4.1717 © 2009-21 package. Analysis of variance was performed and traits that showed significant differences were further subjected to association analysis.

RESULTS AND DISCUSSION

The F test from the analysis of variance revealed a significant difference for all the traits, which indicated the existing genetic variability among parents and hybrids. Our findings were in conformity with that of earlier reports (Rahman *et al*. 2013, Bechere *et al*. 2014, Memon *et al*. 2017, Teodoro *et al*. 2018, Khalid *et al*. 2018 and Kakar *et al*. 2021).

Correlation analysis

The results on phenotypic correlation (Table 1) revealed that the traits *viz.,* number of bolls per plant (r=0.39), boll weight (r=0.54), number of seeds per boll (r=0.31), upper half mean length (r=0.42) and fibre strength (r=0.33) exhibited a significant positive correlation with seed cotton yield. The number of locules per boll (r=-0.28) displayed a significant negative association with seed cotton yield. Previous studies reported by Satish *et al.* 2020 for boll weight, number of bolls per plant; Amelin *et al.* 2020 for number of bolls per plant, fibre length; and Rai and Sangwan. 2020 for number of bolls per plant, boll weight, number of seeds per boll for association with seed cotton yield. It is important to know the inter-relationship among component traits rather than knowing the association between yield and its attributing traits, as these traits have a high influence on yield. Boll weight, the most vital trait for yield improvement in cotton had a significant positive association with plant height (r=0.33), number of bolls per plant (r=0.36), upper half mean length (r=0.50), fibre strength (r=0.38) and elongation percentage (r=0.31). Number of bolls per plant showed significant positive correlation with plant height (r=0.58), number of sympodial branch per plant (r=0.49), boll weight (r=0.36), seed index (r=0.25), upper half mean length (r=0.29) and fibre strength (r=0.36). Seed index has phenotypically correlated with plant height (r=0.25) and number of bolls (r=0.25). The traits *viz.,* plant height (r=0.48), number of monopodial branch per plant (r=0.38), number of bolls per plant (r=0.36), boll weight (r=0.38), upper half

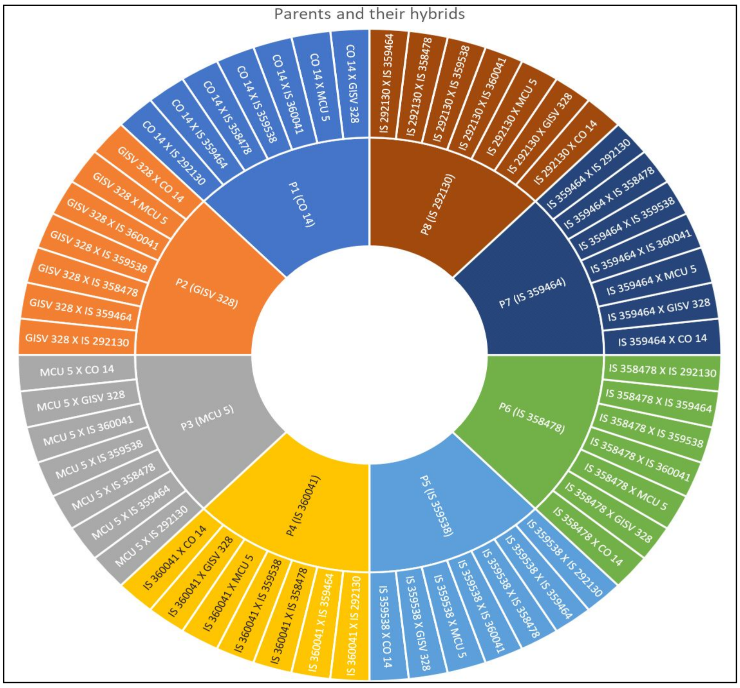

Fig 1: Evaluated parents and hybrids in our study.

Table 1: Phenotypic correlation among yield component and fibre quality traits.

Traits	DFF	DFBB	PH	NMON	NSYM	NOB	NOL	BW	NOS	SCY	SI	LI	UHML	FS	MIC	UI	EP	GOT
DFF	1.00																	
DFBB	0.14	1.00																
PH	-0.14	-0.14	1.00															
NMON	0.04	-0.04	0.27*	1.00														
NSYM	-0.01	0.00	0.63**	0.30*	1.00													
NOB	0.16	-0.06	0.58**	0.24	0.49**	1.00												
NOL	-0.15	0.00	0.19	0.15	0.17	0.06	1.00											
BW	-0.05	-0.06	0.33**	0.03	0.12	0.36**	-0.24	1.00										
NOS	-0.08	-0.11	0.03	-0.12	-0.20	-0.04	-0.11	0.24	1.00									
SCY	0.03	-0.02	0.18	0.08	0.11	0.39**	-0.28*	0.54**	0.31*	1.00								
SI	0.18	0.01	0.25*	0.12	0.20	0.25*	0.10	0.08	0.09	0.08	1.00							
LI	-0.06	-0.01	0.28*	0.14	0.29*	0.15	0.16	0.17	0.00	0.01	0.23	1.00						
UHML	-0.22	-0.06	0.42**	0.25*	0.23	0.29*	0.01	0.50**	-0.05	0.42**	0.07	0.22	1.00					
FS	-0.13	-0.11	0.48**	0.38**	0.21	0.36**	-0.06	0.38**	-0.12	0.33**	0.01	0.12	0.70**	1.00				
MIC	0.00	0.14	-0.05	-0.37**	-0.14	-0.19	-0.03	0.09	-0.02	-0.09	0.13	-0.05	0.03	-0.09	1.00			
UI	0.16	-0.02	-0.25*	-0.18	-0.20	-0.02	-0.05	-0.01	0.15	0.10	0.02	-0.07	-0.55**	-0.39**	0.06	1.00		
EP	-0.19	-0.09	0.36**	0.36**	0.19	0.21	-0.01	0.31*	-0.24	0.20	0.04	0.25*	0.76**	0.83**	0.07	-0.40**	1.00	
GOT	-0.09	-0.08	-0.04	0.05	-0.12	-0.05	0.16	0.05	-0.16	-0.09	0.13	-0.02	0.19	0.13	0.25*	-0.02	0.19	1.00

Note: PH: Plant height (cm); DFF: Days to fifty per cent flowering (number of days); DFBB: Days to first boll bursting (number of days); NMON: Number of monopodia per plant; NSYM: Number of sympodia per plant; NOB: Number of bolls per plant; NOL: Number of locules per boll; BW: Boll weight (g); NOS: Number of seeds per boll; SCY: Seed cotton yield per plant (g); SI: Seed index (g); LI: Lint index (g); GOT: Ginning out turn (%); UHML: Upper half mean length (mm); FS: Fibre strength (g/tex); MIC: Fibre fineness (µg/inch); UI: Uniformity index; EP: Elongation percentage (%).

(**highly significant @ 1%), (*significant @ 5%)

Table 2: Genotypic correlation among yield component and fibre quality traits.

Traits	DFF	DFBB	PH	NMON	NSYM	NOB	NOL	BW	NOS	SCY	SI	LI	UHML	FS	MIC	UI	EP	GOT
DFF	1**																	
DFBB	0.21	1**																
PH	-0.18	-0.16	1**															
NMON	0.03	-0.02	0.31*	1**														
NSYM	0.03	0.05	0.70**	0.38**	1**													
NOB	0.18	-0.07	0.62**	0.25	0.57**	1**												
NOL	-0.14	-0.04	0.29*	0.21	0.18	0.13	1**											
BW	-0.09	-0.02	0.36**	0.04	0.14	0.39**	-0.37**	1**										
NOS	-0.09	-0.17	0.01	-0.14	-0.24	-0.05	-0.12	0.30*	1**									
SCY	0.02	-0.01	0.20	0.09	0.10	0.41**	-0.39**	0.57**	0.35**	1**								
SI	0.21	0.08	0.28*	0.12	0.29*	0.27*	0.24	0.12	0.11	0.10	1**							
LI	-0.03	0.02	0.38**	0.17	0.37**	0.19	0.40**	0.23	0.002	0.01	0.22	1**						
UHML	-0.28*	-0.09	0.50**	0.35**	0.26*	0.36**	-0.05	0.58**	-0.06	0.53**	0.14	0.38**	1**					
FS	-0.15	-0.13	0.52**	0.41**	0.25*	0.38**	-0.04	0.42**	-0.13	0.37**	0.00	0.12	0.77**	1**				
MIC	-0.07	0.24	-0.02	-0.59**	-0.14	-0.24	0.13	0.25*	-0.04	-0.12	0.20	-0.08	0.26*	-0.06	1 **			
UI	0.26*	-0.04	-0.31*	-0.22	-0.26*	-0.05	-0.003	-0.008	0.12	0.13	-0.03	-0.22	-0.70**	-0.48**	0.09	1**		
EP	-0.37**	-0.09	0.56**	0.57**	0.41**	0.34**	-0.007	0.40**	-0.38**	0.34**	0.03	0.49**	0.85**	1.11**	0.49**	-0.58**	1**	
GOT	-0.07	-0.09	-0.02	0.03	-0.11	-0.06	0.18	0.08	-0.17	-0.09	0.19	0.007	0.26*	0.16	0.39**	-0.03	0.33**	1**

Note: PH: Plant height (cm); DFF: Days to fifty per cent flowering (number of days); DFBB: Days to first boll bursting (number of days), NMON: Number of monopodia per plant; NSYM: Number of sympodia per plant; NOB: Number of bolls per plant; NOL: Number of locules per boll; BW: Boll weight (g); NOS: Number of seeds per boll; SCY-Seed cotton yield per plant (g); SI: Seed index (g); LI: Lint index (g); GOT: Ginning out turn (%); UHML: Upper half mean length (mm); FS: Fibre strength (g/tex); MIC: Fibre fineness (µg/inch); UI: Uniformity index; EP: Elongation percentage (%).
(**highly significant @ 1%), (*significant @ 5%).

Table 3: Estimates of direct and indirect effects of yield component and fibre quality traits on seed cotton yield.

Traits	DFF	DFBB	PH	NMON	NSYM	NOB	NOL	BW	NOS	SI	LI	UHML	FS	MIC	UI	EP	GOT	SCY
DFF	0.00	0.01	0.03	0.00	0.00	0.03	0.03	-0.01	-0.02	0.01	0.00	-0.15	-0.03	0.00	0.06	0.06	0.01	0.03
DFBB	0.00	0.04	0.03	0.00	0.00	-0.01	0.00	-0.01	-0.02	0.00	0.00	-0.04	-0.03	0.00	-0.01	0.03	0.01	-0.02
PH	0.00	-0.01	-0.23	0.00	0.08	0.12	-0.03	0.04	0.01	0.01	-0.02	0.29	0.12	0.00	-0.10	-0.11	0.00	0.18
NMON	0.00	0.00	-0.06	0.01	0.04	0.05	-0.03	0.00	-0.03	0.00	-0.01	0.17	0.10	0.01	-0.07	-0.11	-0.01	0.08
NSYM	0.00	0.00	-0.15	0.00	0.13	0.10	-0.03	0.01	-0.04	0.01	-0.02	0.16	0.05	0.00	-0.08	-0.06	0.01	0.11
NOB	0.00	0.00	-0.13	0.00	0.06	0.21	-0.01	0.04	-0.01	0.01	-0.01	0.20	0.09	0.01	-0.01	-0.07	0.01	0.39**
NOL	0.00	0.00	-0.04	0.00	0.02	0.01	-0.17	-0.03	-0.02	0.00	-0.01	0.01	-0.02	0.00	-0.02	0.00	-0.02	-0.28*
BW	0.00	0.00	-0.08	0.00	0.02	0.08	0.04	0.11	0.05	0.00	-0.01	0.34	0.10	0.00	0.00	-0.10	-0.01	0.54**
NOS	0.00	0.00	-0.01	0.00	-0.03	-0.01	0.02	0.03	0.22	0.00	0.00	-0.03	-0.03	0.00	0.06	0.07	0.02	0.31*
SI	0.00	0.00	-0.06	0.00	0.03	0.05	-0.02	0.01	0.02	0.04	-0.02	0.05	0.00	0.00	0.01	-0.01	-0.01	0.08
LI	0.00	0.00	-0.06	0.00	0.04	0.03	-0.03	0.02	0.00	0.01	-0.08	0.15	0.03	0.00	-0.03	-0.08	0.00	0.01
UHML	0.00	0.00	-0.10	0.00	0.03	0.06	0.00	0.06	-0.01	0.00	-0.02	0.68	0.18	0.00	-0.21	-0.24	-0.02	0.42**
FS	0.00	0.00	-0.11	0.01	0.03	0.08	0.01	0.04	-0.03	0.00	-0.01	0.48	0.26	0.00	-0.15	-0.26	-0.01	0.33**
MIC	0.00	0.01	0.01	-0.01	-0.02	-0.04	0.01	0.01	0.00	0.00	0.00	0.02	-0.02	-0.03	0.02	-0.02	-0.03	-0.09
UI	0.00	0.00	0.06	0.00	-0.03	0.00	0.01	0.00	0.03	0.00	0.01	-0.37	-0.10	0.00	0.38	0.12	0.00	0.10
EP	0.00	0.00	-0.08	0.01	0.02	0.04	0.00	0.03	-0.05	0.00	-0.02	0.52	0.22	0.00	-0.15	-0.31	-0.02	0.20
GOT	0.00	0.00	0.01	0.00	-0.02	-0.01	-0.03	0.01	-0.04	0.00	0.00	0.13	0.03	-0.01	-0.01	-0.06	-0.11	-0.09

Residual Effect= 0.4046.

Note: PH: Plant height (cm); DFF: Days to fifty per cent flowering (number of days); DFBB: Days to first boll bursting (number of days); NMON: Number of monopodia per plant; NSYM: Number of sympodia per plant; NOB: Number of bolls per plant; NOL: Number of locules per boll; BW: Boll weight (g); NOS: Number of seeds per boll; SCY: Seed cotton yield per plant (g); SI: Seed index (g); LI: Lint index (g); GOT: Ginning out turn (%); UHML: Upper half mean length (mm); FS: Fibre strength (g/tex); MIC: Fibre fineness (µg/inch); UI: Uniformity index; EP: Elongation percentage (%).

(**highly significant @ 1%), (*significant @ 5%).

mean length (r=0.70) and elongation percentage (r=0.83) revealed significant positive association with fibre strength, while uniformity index (r=-0.39) has shown a significant negative correlation with fibre strength.

Genotypic correlation (Table 2) revealed that the traits *viz.,* number of bolls per plant (r=0.41), boll weight (r=0.57), number of seeds per boll (r=0.35), upper half mean length (r=0.53), fibre strength (r=0.37) and elongation percentage (r=0.34) displayed highly significant positive association with seed cotton yield, while the number of locules (r=-0.39) exhibited a highly significant negative correlation with seed cotton yield. Similar results were also reported by number of researchers (Satish *et al.* 2020, Manonmani *et al.* 2019, Chaudhari *et al.* 2017, Farooq *et al.*2014 and Rahman *et al.* 2013). In terms of inter-relationship among component traits, boll weight was reported to have a highly significant positive association with plant height (r=0.36), number of bolls per plant (r=0.39), number of seeds per boll (r=0.30), upper half mean length (r=0.58), fibre strength (r=0.42), fibre fineness (r=0.25) and elongation percentage (r=0.40), whereas the association of boll weight was negative with the number of locules per boll (r=-0.37). The traits such as plant height (r=0.62), number of sympodial branch per plant (r=0.57), boll weight (r=0.39), seed index (r=0.27), upper half mean length (r=0.36) and fibre strength (r=0.38) and elongation percentage (r=0.34) shown significant positive correlation with number of bolls per plant. A similar pattern was reported by Shaheen *et al.*2021, Rai and Sangwan. 2020, Gnanasekaran *et al.* 2020, Ahmed *et al.* 2019 and Monisha *et al.* 2018. Fibre length is an essential criterion for the textile industry, thus upper half mean length of the fibre has a positive association with all the traits except days to first boll bursting, number of locules per boll, number of seeds per boll and seed index. Upper half mean length has negatively correlated with days to fifty per cent flowering (r=-0.28) and uniformity index (r=-0.70). From correlation analyses, it was concluded that the traits exhibited higher genotypic correlation values than phenotypic correlation values and thus revealing the strong association between the dependent trait (yield) and independent traits (yield component traits) genetically with less environmental interaction. Further, these traits *viz.,* number of bolls per plant, boll weight, number of seeds per boll, upper half mean length and fibre strength were in significant association with seed cotton yield both phenotypically and genotypically, hence selection for these traits will positively enhance the yield.

Path analysis

A path coefficient analysis can simplify the exact inter-relationship among yield component traits and the influence of each trait on a highly dependent variable. The residual effect in path analysis measures the best of causal factors that account for variability in the effect of the dependent variable. In our study, the residual effect (0.40) explained that the trait included in this study is adequate, which means the eighteen traits comprised in this study has more impact on the dependent variable (yield). Diagonal values represent the direct effect on seed cotton yield. Estimate of direct effect (Table 3) portrayed that the trait, upper half mean length (0.68) and uniformity index (0.38) exerted a positive direct effect of higher magnitude on seed cotton yield while, number of bolls per plant (0.21), number of seeds per boll (0.22) and fibre strength (0.26) exerted a moderate positive direct effect on seed cotton yield. Plant height (-0.23) and elongation percentage (-0.31) had a negative direct effect on seed cotton yield. Previous studies on the cause-and-effect relationship by Rahman *et al.* 2013, Farooq *et al.* 2014, Pujer *et al.* 2014, Farias *et al.* 2016 and Chaudhari *et al.* 2017 also reported similar outcomes. The number of bolls per plant that showed a positive correlation with seed cotton yield had negligible indirect effect via upper half mean length, number of sympodial branch per plant, boll weight, seed index and fibre strength. Boll weight exhibited indirect effect via number of sympodial branch per plant, number of bolls per plant, number of locules per boll, number of seeds per boll, upper half mean length and fibre strength on seed cotton yield. The upper half mean length had a low direct effect on seed cotton yield via fibre strength. Fibre strength exerted a high indirect effect on seed cotton yield via upper half mean length.

Thus, path analysis signified that the traits namely upper half mean length, number of bolls per plant and fibre strength had major impact on seed cotton yield both directly and indirectly. Hence, these traits were good selection indicators for yield improvement in cotton.

CONCLUSION

The correlation analysis displayed that number of bolls per plant, boll weight, number of seeds per boll, upper half mean length and fibre strength had a high magnitude of positive correlation with seed cotton yield at both genotypic and phenotypic levels. Selection based on these traits would enhance the yield genetically with less influence from the environment. Path analysis explained positive direct effect by upper half mean length, uniformity index, number of bolls per plant and number of seeds per boll and fibre strength on seed cotton yield. These traits show a high correlation and direct effect on seed cotton yield, thus concluding the fact that improvement of these traits will simultaneously boost the seed cotton yield.

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Conflict of interest: None.

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