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Research Article

Association studies with direct and indirect effects among different morpho-bio traits in *Gossypium arboreum*

Pooja, Omender Sangwan, S.R Pundir, Meenakshi Rathi* and Shivani Mandhania

Department of Genetics and Plant Breeding,Chaudhary Charan Singh Haryana Agricultural University, Hisar 125004, India
***E-Mail**:meenakshirathi55@gmail.com

Abstract
The experiment was carried out at the Research Area of Cotton Section and Biochemistry Laboratory, Department of Genetics and Plant Breeding, CCSHAU, Hisar (Haryana, India) during *kharif* 2017-18. The observations were recorded for different morphological and biochemical characters to assess the association among the traits and to estimate the direct-indirect effects through path analysis. Seed cotton yield was found positively correlated with various traits; strongest among them were lint yield (0.954, 0.956), boll weight (0.742, 0.768), and the number of bolls per plant (0.771, 0.799) at both phenotypic and genotypic levels. Path coefficient analysis revealed that the highest direct effect is contributed by boll weight (1.198) followed by the number of bolls per plant (1.181) to the seed cotton yield. Thus these two traits play a major role in the selection of high yielding seed cotton genotypes.

Key words
Phenotypic correlation, Genotypic correlation, Path coefficient, Direct-indirect effects, Seed cotton yield.

INTRODUCTION

In India, cotton is the main commercial fibre crop. It is the king of fiber and an important cash crop exercising a profound influence on economics and social affairs of the world. In India, cotton provides means of livelihood to millions of farmers and workers. The crop is cultivated in about 70 countries across the world and planted in an area of 31.8 million hectares. India, China, and the United States of America are the top three cotton-producing countries. India produced about 30.08 million bales of cotton, which makes it the largest producer of cotton accounting for one-fourth of global cotton production. (ICAC, 2018-19).

Cotton seed is used for the production of edible oil, protein, and other by-products (Harijan *et al*., 2016). The linters are used to make coarse yarns and many cellulose products. Cotton oil is used for the preparation of alkyl resins for interior paints, special bio-lubricants, and soft soaps which are directly or indirectly utilized in human food and livestock (Saxena *et al*., 2011). The oil is also used in salads as it has good oxidative stability due to its high antioxidant tocopherol contents and oleic acid (Sekhar and Rao, 2011). Thus increasing the seed cotton yield is important and needed but the seed cotton yield itself is a complex character and a product of interplay between its attributes coupled with varying environmental conditions (Ahmad *et al*., 2017; Khan *et al*., 2010). Different traits indicate correlation among themselves. Therefore, information of inter-relationship between yield and yield contributing traits are necessary for simultaneous improvement in these traits. In addition to this, path co-efficient analysis (Croxton and Cowden, 1964) was used for obtaining direct, and indirect effects of quantitative traits on seed cotton yield and inter-

relations can be examined between them. Sometimes co-relation studies alone are ambiguous, therefore, the above study will be more beneficial. In this paper, an attempt is made to study correlation and path coefficient in respect to seed cotton yield with other traits.

MATERIALS AND METHODS

The experimental materials comprised of 60 Desi cotton genotypes taken from cotton germplasm maintained at Cotton Section, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India. A list of these genotypes is given in **Table 1**. The above experimental material was planted during *kharif* season of 2017-18. Each genotype was planted in two rows of 2.7 meter length in Randomized Block Design with three replications. The spacing of 67.5 cm between rows and 30 cm between plants was maintained. Normal cultural practices recommended for desi cotton were adopted throughout the crop seasons. The morphological and biochemical data were recorded on various traits.

Phenotypic and genotypic correlation coefficients were worked out using the variance-covariance matrix as described by Croxton and Cowden (1964). Path-co-efficient analysis was done using the formula given by Dewey and Lu (1959) to measure the direct influence of one variable upon the other.

Table 1. Evaluation of *desi* cotton genotypes/ germplasm lines

S.No.	GENOTYPES	S.No.	GENOTYPES	S.No.	GENOTYPES
1	Arlano	21	FFS-1	41	HD 20
2	AC 8	22	FFS-2	42	HD 302
3	AC 33	23	FFS-3	43	HD 351
4	B 2-16-2	24	FFS-4	44	HD 372
5	B-4	25	FFS-5	45	HD392
6	BH 30	26	FFS-6	46	HD 404
7	BH 41	27	FFS-7	47	HD 408
8	BH 92	28	FFS-8	48	HD 479-1
9	BH 102	29	FFS-9	49	HD 479-2
10	BHO 5 VIII	30	G 20	50	HD 514
11	BPS	31	G 23	51	HD 524
12	D 43-21	32	Gao-16 LB VI	52	HD 2204
13	D 48-154-1	33	Garovilli	53	HD 2446
14	D 462-1-1	34	GOV 6	54	HD 5278
15	DC-93	35	H 1	55	N-W-1
16	DC 108	36	H 476-5	56	PL 735-1
17	DS-5	37	H 52 -519	57	PL 735-2
18	DS 5	38	HD 3	58	RA 1
19	DS 1	39	HD 6	59	Y-1
20	EB 31-1	40	HD 10	60	35/5 B

RESULTS AND DISCUSSION

To improve seed cotton yield, it is essential to know the relationship of different quantitative and biochemical traits with it so that the selection can be made effectively. It is important to have knowledge about the nature and magnitude of the association between various traits to perform the selection in the right direction. The correlation co-efficient at both genotypic and phenotypic level is given in **Table 2**.

Seed cotton yield was found positively correlated with almost all the traits except for days to flower, ginning outturn, and gossypol content. These three traits exhibited a negative correlation with values –0.122,-0.047, -0.027 at the phenotypic level, and -0.156, -0.046 and -0.028 at the genotypic level respectively. All values were not significant except days to flower at genotypic level which means when the reproduction stage comes later in the plant yield is compromised. Kumar and Ravikesavan (2010) also reported a negative correlation of days to flower and ginning outturn with seed cotton. This shows that more is the days to flower lesser will be the seed cotton yield thus for the higher yield of cotton seed, days to flower will be selected in the negative direction. Maximum positive and significant correlation was found with lint yield (0.954, 0.956) at both phenotypic and genotypic levels followed by boll weight (0.742, 0.768) and the number of bolls per plant (0.771, 0.799). It infers that more is the lint yield; the number of bolls and boll weight more will be the seed cotton yield. Hence, these three traits play a major role in selection traits like plant height, the number of monopods per plant, the number of sympods per plant, seed index and lint index had a positive and significant correlation with seed cotton yield. Thiyagu and Gunasekaran (2020)

revealed that plant height, the number of sympodia per plant, the number of monopodia per plant and the number of bolls per plant exhibited positive association with seed cotton yield per plant. Whereas gossypol content, oil content and protein content did not show any significant relation with the cotton seed yield. Similar findings were reported by Farooq *et al.* (2014) and Rathinavel *et al.* (2017) regarding correlation studies, traits *viz*. bolls per plant, plant height and boll weight had a positive genotypic correlation with cotton seed yield. Sympodial branches, bolls per plant, boll weight and lint index were found to be positively correlated with yield per plant in all the genotypes by Salahuddin *et al*. (2010). Latif *et al*. (2015) reported a positive association of bolls per plant, sympodia per plant, and boll weight with seed cotton yields in their experiments. The protein content is found

Table 2. Genotypic correlation coefficients (above diagonal) and phenotypic correlation coefficients (below diagonal) for seed cotton yield and other characters in *desi* cotton

Character	DTF	PH	NM/P	NS/P	NB/P	BW	LY/P	SI	LI	GOT	OC	PC	GC	SCY/P
DTF	**1.00**	-0.144	-0.527**	-0.325**	-0.279**	0.038	-0.025	-0.251**	0.213**	0.456**	-0.084	-0.237**	-0.056	-0.156*
PH	-0.097	**1.00**	-0.144	0.425**	0.248**	0.019	0.147*	0.299**	0.124	-0.118	0.083	-0.006	0.206**	0.179*
NM/P	-0.124	-0.027	**1.00**	0.371**	0.540**	0.375**	0.603**	0.280**	0.297**	0.051	-0.029	0.405**	-0.057	0.601**
NS/P	-0.217**	0.326**	0.101	**1.00**	0.353**	0.192**	0.330**	0.156*	0.112	-0.02	0.129	-0.149*	0.269**	0.337**
NB/P	-0.208**	0.217**	0.251**	0.263**	**1.00**	0.239**	0.757**	0.213**	0.12	-0.065	0.067	0.114	0.04	0.799**
BW	0.031	0.017	0.119	0.187*	0.160*	**1.00**	0.744**	0.319**	0.275**	0.003	-0.043	0.087	-0.083	0.768**
LI/P	-0.016	0.135	0.247**	0.292**	0.727**	0.717**	**1.00**	0.216**	0.411**	0.242**	0.047	0.063	-0.014	0.956**
SI	-0.219**	0.241**	0.101	0.094	0.203**	0.285**	0.208**	**1.00**	0.490**	-0.365**	-0.128	0.202**	0.042	0.335**
LI	0.159*	0.112	0.082	0.076	0.104	0.236**	0.398**	0.498**	**1.00**	0.630**	0.021	0.004	0.024	0.240**
GOT	0.364**	-0.075	-0.005	0.001	-0.066	0.003	0.249**	-0.331**	0.649**	**1.00**	0.126	-0.177*	0.008	-0.046
OI	-0.079	0.051	0.015	0.097	0.057	-0.028	0.048	-0.115	0.023	0.116	**1.00**	-0.038	-0.028	0.003
PRO	-0.194**	-0.005	0.162*	-0.115	0.114	0.073	0.061	0.192**	0.007	-0.162*	-0.038	**1.00**	0.106	0.104
GOS	-0.045	0.166*	-0.02	0.203**	0.038	-0.079	-0.013	0.042	0.024	0.008	-0.027	0.105	**1.00**	-0.028
SCY/P	-0.122	0.158*	0.255**	0.293**	0.771**	0.742**	0.954**	0.320**	0.216**	-0.047	0.007	0.1	-0.027	**1.00**

*** Significant at p= 0.05, ** Significant at p= 0.01**
DTF- Days to first flower, **PH-** Plant height , **NM/P-**Number of monopods/plant, **NS/P-**Number of sympods/plant, **NB/P-**Number of bolls/plant, **BW-** Boll weight , **SCY/P-** Seed cotton yield/Plant , **LY/P-**lint yield/plant**, SI-** Seed index , **LI-** Lint index, **GOT-** Ginning out turn, **OC-** Oil content, **PC-** Protein content , **GC-** Gossypol content .

negatively and significantly correlated with days to flower (-0.194, -0.237) which means when days to flower are more, protein content is reduced. Hence, for selecting genotypes with higher protein content we can do a selection for early flowering.

The association between seed cotton yield and its components is the clear consequence of the direct effect of some components and indirect effects via other yield contributing traits. The direct effect might not be the same as the identified correlation between seed cotton yield and its component traits. Correlation studies may be misdirecting in some cases. It can be overestimated or underestimated due to direct relationship with different traits. Thus, a direct selection based on of correlated response may not be productive. At a point, when numerous traits are influencing a given character, it is essential to divide the whole correlation into direct and indirect effects brought about by way of path coefficient study. Direct-indirect effects of various traits with seed cotton yield are provided in **Table 3** and **Fig.1** shows the same in a diagrammatic way.

The highest direct effect is contributed by boll weight (1.198) followed by the number of bolls per plant (1.181) to the seed cotton yield. Asha *et al*. (2015) observed that bolls /plant and boll weight had a positive direct effect on seed cotton yield /plant. Similarly, Srinivas *et al.* (2015) also revealed that the number of bolls /plant and boll weight exhibited a maximum direct effect on yield. The path study again shows that the number of bolls and boll weight is vital traits for selection in a positive direction. Other characters like the number of monopods (0.607) and ginning outturn (0.658) also affects seed cotton yield directly and positively. Thus selecting these traits we can achieve higher seed cotton yield. Days to flower, plant height the number of sympods, and seed index also has positive effect on the yield of a plant, whereas lint yield has a direct negative effect on the seed cotton yield with value -1.122. Whereas correlation showed a positive association this shows that it does not affect seed cotton yield directly rather uses different path via other traits. Reddy *et al*. (2015) reported that the number of bolls /plant, seed index, boll weight , and lint yield / plant showed direct positive effects. Protein content was

Table 3. Direct (diagonal) and indirect effect of various characters on seed cotton yield in desi cotton

Character	DTF	PH	NM/P	NS/P	NB/P	BW	LY/P	SI	LI	GOT	OC	PC	GC	Correlation with SCY/P
DTF	**0.264**	-0.039	-0.32	0.078	-0.33	0.046	0.028	-0.099	-0.133	0.3	-0.004	0.059	-0.005	-0.156*
PH	-0.038	**0.269**	-0.087	-0.101	0.293	0.022	-0.165	0.118	-0.077	-0.077	0.004	0.001	0.018	0.179*
NM/P	-0.139	-0.039	**0.607**	-0.089	0.637	0.449	-0.677	0.11	-0.185	0.034	-0.002	-0.101	-0.005	0.601**
NS/P	-0.086	0.114	0.225	**0.239**	0.416	0.23	-0.371	0.061	-0.07	-0.013	0.007	0.037	0.024	0.337**
NB/P	-0.074	0.067	0.328	-0.084	**1.181**	0.286	-0.849	0.084	-0.075	-0.043	0.003	-0.029	0.004	0.799**
BW	0.01	0.005	0.228	-0.046	0.282	**1.198**	-0.835	0.126	-0.171	0.002	-0.002	-0.022	-0.007	0.768**
LY/P	-0.006	0.04	0.366	-0.079	0.894	0.891	**-1.122**	0.085	-0.256	0.159	0.002	-0.016	-0.001	0.956**
SI	-0.066	0.08	0.17	-0.037	0.252	0.382	-0.242	**0.394**	-0.305	-0.24	-0.007	-0.05	0.004	0.335**
LI	0.056	0.033	0.18	-0.027	0.141	0.329	-0.461	0.193	**-0.622**	0.414	0.001	-0.001	0.002	0.240**
GOT	0.12	-0.032	0.031	0.005	-0.077	0.004	-0.271	-0.144	-0.392	**0.658**	0.006	0.044	0.001	-0.046
OC	-0.022	0.022	-0.018	-0.031	0.079	-0.052	-0.053	-0.05	-0.013	0.083	**0.051**	0.009	-0.002	0.003
PC	-0.063	-0.002	0.246	0.036	0.135	0.104	-0.07	0.08	-0.003	-0.116	-0.002	**-0.25**	0.009	0.104
GC	-0.015	0.055	-0.035	-0.064	0.047	-0.1	0.016	0.017	-0.015	0.005	-0.001	-0.027	**0.088**	-0.028

Residual effect= 1.0053

DTF- Days to first flower, **PH-** Plant height , **NM/P-** Number of monopods/plant, **NS/P-** Number of sympods/plant, **NB/P-** Number of bolls/plant, **BW-** Boll weight , **SCY/P-** Seed cotton yield/Plant , **LY/P-**lint yield/plant**, SI-** Seed index , **LI-** Lint index, **GOT-** Ginning out turn , **OC-** Oil content , **PC-** Protein content , **GC-** Gossypol content

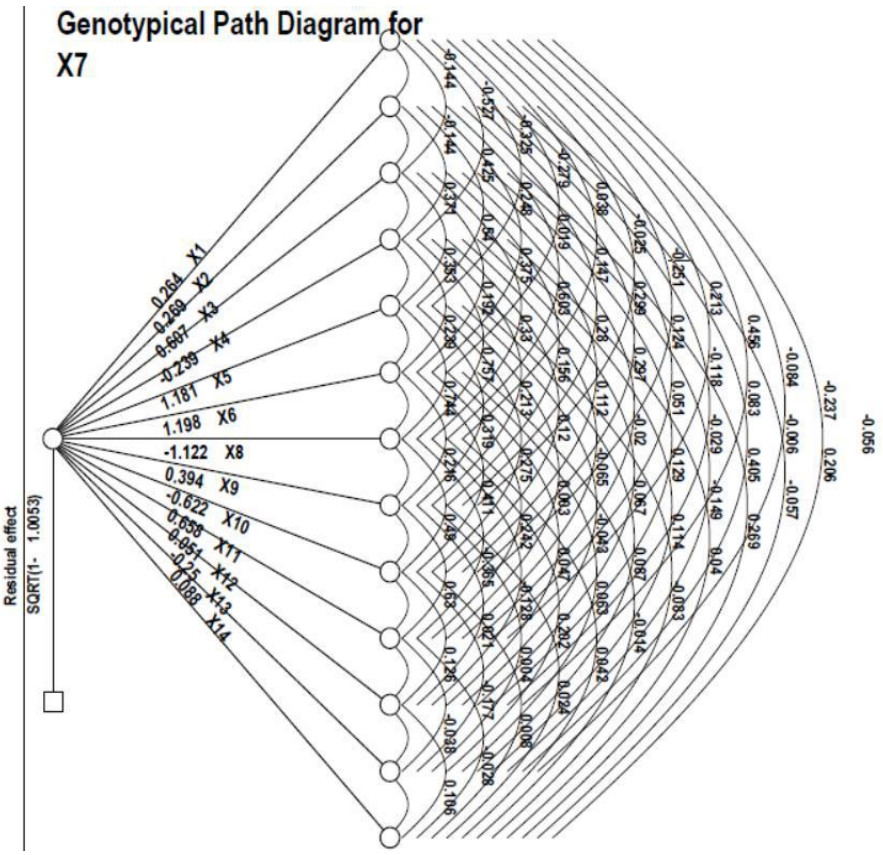

Fig. 1. Path diagram for seed cotton yield and its contributing traits

also found in having a negative effect on seed cotton yield in the studies. Kumar and Ravikesavan (2010) also found that seed cotton yield was influenced in a negative direction by days to first flower, the number of monopods, and seed oil.

Taking other traits into consideration it was found that the number of monopods indirectly affects the number of bolls (0.328), lint yield (0.366), and the number of sympods (0.225). Oil content, gossypol content, and protein content does not affect seed cotton yield directly or indirectly. Vinodhana *et al.* (2013) revealed indirect effects of plant height influenced the seed cotton yield through the number of bolls /plant, boll weight, ginning percentage, seed index and lint index. Latif *et al*. (2015) depicted that plant height and seed index had a negative direct effect on yield. Sympods /plant and boll weight depicted maximum indirect positive effect on seed yield via the number of bolls /plant. In this study monopods / plant put undeviating and highly positive effect on yield via the number of bolls /plant.

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