Association and Path Analysis in American Cotton (*Gossypium hirsutum* L.)

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ABSTRACT

Fifty five diverse genotypes of American cotton (*Gossypium hirsutum* L.) were evaluated for 17 qualitative and quantitative traits. The correlation study revealed that seed cotton yield was found to be positively and significantly correlated with traits like no. of bolls plant^{-1}, boll weight, ginning out turn and lint yield plant^{-1} at both phenotypic and genotypic levels. Path coefficient analysis revealed high positive direct effect of number of bolls plant^{-1}, boll weight and lint yield plant^{-1} on seed cotton yield plant^{-1}. The correlation and path analysis therefore clearly indicated that direct selection based on bolls plant^{-1} and boll weight may be helpful in developing high seed cotton yield varieties in upland cotton.

Key words: *Character association, Gossypium hirsutum , path analysis*

Cotton being an important cash crop of India plays a distinguished role in energizing the economy of the country by fetching appreciable amount of foreign exchange annually. In India, cotton is being grown over an area of 126.55 lakh ha with an annual production of 400 lakh bales (1 bale=170 kgs of lint) with a productivity of 537 kg/ha (AICCIP Annual Report, 2014-15). Yield is a polygenically inherited character resulting from multiplicative interaction of its contributing characters. Correlation coefficient analysis measures the magnitude of relationship between various plant characters and determines the component character on which selection can be based for improvement in seed cotton yield and fibre quality. When more characters are involved in the correlation study, it becomes difficult to ascertain the characters which really contributed towards yield. Path coefficient analysis helps to partition the observed correlation coefficients into components of direct and indirect influences and provides perceptions for the characterizations of more complex traits. The present study is palnned in that direction and the information generated from it will be useful to understand the association of yield contributing and fibre quality characters, their direct contribution to yield, and indirect effects through other characters on yield of cotton.

MATERIAL AND METHODS

The present study was conducted during *kharif*, 2013-14 in randomized block design with 55 genotypes (45 F_1s and 10 parents) with three replications following 120 x 60 cm spacing at Agricultural Research Station, Darsi, Prakasam district, Andhra Pradesh. Recommended doses of fertilizers 120 N, 60 P_2O_5 and 40 K_2O kg/ha were applied in split doses. Each plot consisted of three rows of 6 m length and observations were recorded on five randomly selected plants from each genotype per replication for 17 characters *viz*., plant height (cm), no. of monopodia plant^{-1}, no. of sympodia plant^{-1}, no. of bolls plant^{-1}, boll weight (g), chlorophyll content (mg g^{-1} fresh weight), seed index (g), lint index (g), seed cotton yield plant^{-1} (g) and lint yield plant^{-1} (g). The data on days to 50% flowering, ginning out turn (%), 2.5% span length (mm), micronaire value (10^{-6}g/inch), bundle strength (g/tex), uniformity ratio and elongation (%) were recorded on plot basis. The fibre quality parameters were studied at Central Institute for Research on Cotton Technology (CIRCOT), RARS, Lam, Guntur, Andhra Pradesh. The data was statistically analysed to estimate genotypic and phenotypic correlation coefficients and path coefficients analysis as per the formula given by Falconer, 1964 and Dewey and Lu, 1959 respectively.

Table 1. Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients for seed yield and yield traits of cotton at ARS, Darsi during *kharif*, 2013-14.

Character	Days to 50 % flowering	Plant height	No. of monopodia plant^{-1}	No. of sympodia plant^{-1}	No. of bolls plant^{-1}	Boll weight	Chlorophyll content	Seed index
Days to 50 % flowering	—-	-0.0046	-0.0312	-0.1378	0.0710	0.0161	-0.0154	-0.1027
Plant height	-0.0093	—-	0.1216	0.4234**	-0.0281	0.1210	0.0862	0.1985*
No. of monopodia plant^{-1}	-0.2212**	0.2553**	—-	0.1836*	0.2012**	0.0407	-0.0776	-0.1500
No. of sympodia plant^{-1}	-0.1714*	0.5399**	0.3216**	—-	0.1586*	-0.0139	0.0518	0.1052
No. of bolls plant^{-1}	0.0710	-0.1078	0.5429**	0.1851*	—-	0.1688*	-0.0534	-0.2664**
Boll weight	0.0187	0.1278	0.2722**	0.0268	0.1551*	—-	-0.1131	0.1604*
Chlorophyll content	-0.0300	0.2501**	-0.3952**	0.0247	-0.1625*	-0.4224**	—-	0.1215
Seed index	-0.1047	0.2733**	-0.3269**	0.1344	-0.3168**	0.1989*	0.2980**	—-
Lint index	-0.2002**	0.2537**	-0.3211**	0.0948	-0.1101	0.2193**	0.0847	0.7909**
Ginning out turn	0.0386	0.0083	0.0942	-0.0540	0.3834**	0.0280	-0.2792**	-0.3566**
2.5% span length	-0.1057	-0.2082**	-0.0545	0.1624*	0.0422	0.0969	0.2085**	0.2080**
Micronaire value	-0.1514	0.2808**	-0.0629	0.3587**	0.0452	0.2431**	-0.2291**	0.2305**
Budnle strength	0.0636	-0.2296**	-0.0110	0.0509	0.0947	0.1041	0.4136**	0.2108**
Uniformity ratio	-0.0020	0.1593*	0.4367**	-0.0523	0.3079**	-0.1912*	0.4232**	-0.1035
Elongation	0.1521	-0.2734**	-0.2368**	0.0338	0.4374**	0.0459	-0.0636	0.0858
Lint yield plant^{-1}	0.0419	0.0157	0.3666**	0.0897	0.7155**	0.5412**	-0.4130**	-0.2457**
Seed cotton yield plant^{-1} (P)	0.0393	0.1089	0.1399	0.0772	0.6229**	0.7539**	-0.0827	-0.0263
Seed cotton yield plant^{-1} (G)	0.0445	-0.0151	0.5188**	0.1244	0.7585**	0.8883**	-0.4640**	-0.0425

Character	Lint index	Ginning out turn	2.5% span length	Micronaire value	Budnle strength	Uniformity ratio	Elongation	Lint yield plant^{-1}
Days to 50 % flowering	-0.1811*	0.0495	-0.0439	-0.1372	0.0109	0.0225	0.1214	0.0502
Plant height	0.1772*	-0.0141	-0.0584	0.2323**	-0.1263	-0.0087	-0.1393	0.0370
No. of monopodia plant^{-1}	-0.1381	0.0528	-0.0779	0.0144	-0.0321	0.0904	-0.0344	0.1282
No. of sympodia plant^{-1}	0.0776	-0.0472	0.1290	0.2675**	0.0265	0.0162	0.0580	0.0526
No. of bolls plant^{-1}	-0.0913	0.3052	0.0222	0.0347	0.0654	0.0848	0.1627*	0.6816**
Boll weight	0.1810*	0.0401	0.0243	0.1882*	0.0221	-0.2375**	0.0328	0.5813**
Chlorophyll content	0.0568	-0.0718	-0.1051	-0.0700	0.0578	0.0539	-0.0141	-0.1244
Seed index	0.7689**	-0.3668	0.1315	0.2058**	0.1290	-0.0638	0.0319	-0.2389**
Lint index	—-	0.2205	0.1996*	0.1859*	0.1529*	-0.1619*	0.0488	0.1891*
Ginning out turn	0.1938*	—-	0.0310	-0.0960	-0.0006	-0.1844*	-0.0055	0.7147**
2.5% span length	0.3317**	0.1081	—-	-0.2455**	0.3924**	-0.1949*	-0.0429	0.0592
Micronaire value	0.2047**	-0.1167	-0.4134**	—-	-0.2247**	0.1437	0.2181**	0.0395
Budnle strength	0.1982*	-0.1025	0.8514**	-0.4090**	—-	-0.1498	0.0438	0.0509
Uniformity ratio	-0.2530**	-0.2937**	-0.7694**	0.2314**	-0.2685**	—-	0.1922*	-0.1979*
Elongation	0.1649*	0.0990	-0.2274**	0.6247**	0.3848**	0.5418**	—-	0.0709
Lint yield plant^{-1}	0.1828*	0.7530**	0.1795*	0.0427	0.0519	-0.1671*	0.2290**	—-
Seed cotton yield plant^{-1} (P)	0.0820	0.1851*	0.0619	0.1357	0.0698	-0.1519	0.1043	0.7530**
Seed cotton yield plant^{-1} (G)	0.1141	0.2809**	0.1016	0.1904*	0.1156	0.0600	0.2091**	0.8910**

*significant at 5% level   **significant at 1% level

Table 2. Direct and indirect effects (phenotypic) of yield components on seed cotton yield of cotton at ARS, Darsi during *kharif*, 2013-14.

Character	Days to 50 % flowering	Plant height	No. of monopodia plant^{-1}	No. of sympodia plant^{-1}	No. of bolls plant^{-1}	Boll weight	Chlorophyll content	Seed index
Days to 50 % flowering	-0.0088	0.0000	0.0003	0.0012	-0.0006	-0.0001	0.0001	0.0009
Plant height	-0.0003	0.0709	0.0086	0.0300	-0.0020	0.0086	0.0061	0.0141
No. of monopodia plant^{-1}	-0.0007	0.0026	0.0217	0.0040	0.0044	0.0009	-0.0017	-0.0033
No. of sympodia plant^{-1}	0.0077	-0.0236	-0.0102	-0.0556	-0.0088	0.0008	-0.0029	-0.0059
No. of bolls plant^{-1}	0.0134	-0.0053	0.0379	0.0299	0.1885	0.0318	-0.0101	-0.0502
Boll weight	0.0045	0.0337	0.0114	-0.0039	0.0470	0.2785	-0.0315	0.0447
Chlorophyll content	-0.0004	0.0025	-0.0022	0.0015	-0.0015	-0.0033	0.0290	0.0035
Seed index	-0.0039	0.0075	-0.0056	0.0040	-0.0100	0.0060	0.0046	0.0376
Lint index	0.0114	-0.0111	0.0087	-0.0049	0.0057	-0.0114	-0.0036	-0.0484
Ginning out turn	-0.0202	0.0057	-0.0215	0.0192	-0.1245	-0.0163	0.0293	0.1496
2.5% span length	-0.0016	-0.0022	-0.0029	0.0048	0.0008	0.0009	-0.0039	0.0049
Micronaire value	-0.0028	0.0047	0.0003	0.0055	0.0007	0.0038	-0.0014	0.0042
Budnle strength	0.0001	-0.0013	-0.0003	0.0003	0.0007	0.0002	0.0006	0.0013
Uniformity ratio	-0.0008	0.0003	-0.0032	-0.0006	-0.0030	0.0083	-0.0019	0.0022
Elongation	0.0035	-0.0040	-0.0010	0.0017	0.0047	0.0009	-0.0004	0.0009
Lint yield plant^{-1}	0.0383	0.0283	0.0980	0.0402	0.5208	0.4441	-0.0951	-0.1826
Seed cotton yield plant^{-1}	0.0393	0.1089	0.1399	0.0772	0.6229	0.7539	-0.0827	-0.0263

Character	Lint index	Ginning out turn	2.5% span length	Micronaire value	Budnle strength	Uniformity ratio	Elongation	Lint yield plant^{-1}
Days to 50 % flowering	0.0016	-0.0004	0.0004	0.0012	-0.0001	-0.0002	-0.0011	-0.0004
Plant height	0.0126	-0.0010	-0.0041	0.0165	-0.0090	-0.0006	-0.0099	0.0026
No. of monopodia plant^{-1}	-0.0030	0.0011	-0.0017	0.0003	-0.0007	0.0020	-0.0007	0.0028
No. of sympodia plant^{-1}	-0.0043	0.0026	-0.0072	-0.0149	-0.0015	-0.0009	-0.0032	-0.0029
No. of bolls plant^{-1}	-0.0172	0.0575	0.0042	0.0065	0.0123	0.0160	0.0307	0.1285
Boll weight	0.0504	0.0112	0.0068	0.0524	0.0061	-0.0662	0.0091	0.1619
Chlorophyll content	0.0016	-0.0021	-0.0030	-0.0020	0.0017	0.0016	-0.0004	-0.0036
Seed index	0.0289	-0.0138	0.0049	0.0077	0.0049	-0.0024	0.0012	-0.0090
Lint index	-0.0629	-0.0139	-0.0126	-0.0117	-0.0096	0.0102	-0.0031	-0.0119
Ginning out turn	-0.0899	-0.4078	-0.0126	0.0392	0.0002	0.0752	0.0022	-0.2915
2.5% span length	0.0074	0.0011	0.0370	-0.0091	0.0145	-0.0072	-0.0016	0.0022
Micronaire value	0.0038	-0.0020	-0.0050	0.0204	-0.0046	0.0029	0.0045	0.0008
Budnle strength	0.0015	0.0000	0.0040	-0.0023	0.0101	-0.0015	0.0004	0.0005
Uniformity ratio	0.0057	0.0065	0.0068	-0.0050	0.0052	-0.0350	-0.0067	0.0069
Elongation	0.0014	-0.0002	-0.0012	0.0062	0.0013	0.0055	0.0286	0.0020
Lint yield plant^{-1}	0.1445	0.5461	0.0453	0.0302	0.0389	-0.1512	0.0542	0.7641
Seed cotton yield plant^{-1}	0.0820	0.1851	0.0619	0.1357	0.0698	-0.1519	0.1043	0.7530

Residual effect = 0.4013

*Significant at 5% level　　**Significant at 1% level　Bold and diagonal values indicate direct effects

Table 3. Direct and indirect effects (Genotypic) of yield components on seed cotton yield of cotton at ARS, Darsi during *kharif*, 2013-14.

Character	Days to 50 % flowering	Plant height	No. of monopodia plant⁻¹	No. of sympodia plant⁻¹	No. of bolls plant⁻¹	Boll weight	Chlorophyll content	Seed index
Days to 50 % flowering	0.0973	-0.0009	-0.0215	-0.0167	0.0069	0.0018	-0.0029	-0.0102
Plant height	0.0034	-0.3643	-0.0930	-0.1967	0.0393	-0.0466	-0.0911	-0.0996
No. of monopodia plant⁻¹	-0.0046	0.0053	0.0208	0.0067	0.0113	0.0057	-0.0082	-0.0068
No. of sympodia plant⁻¹	-0.0484	0.1524	0.0908	0.2822	0.0522	0.0076	0.0070	0.0379
No. of bolls plant⁻¹	0.0725	-0.1102	0.5549	0.1892	1.0222	0.1585	-0.1661	-0.3238
Boll weight	0.0276	0.1894	0.4032	0.0397	0.2298	1.4815	-0.6258	0.2946
Chlorophyll content	-0.0077	0.0644	-0.1017	0.0064	-0.0418	-0.1088	0.2574	0.0767
Seed index	0.0390	-0.1018	0.1218	-0.0501	0.1180	-0.0741	-0.1110	-0.3725
Lint index	-0.0922	0.1168	-0.1478	0.0436	-0.0507	0.1010	0.0390	0.3640
Ginning out turn	0.0185	0.0040	0.0452	-0.0259	0.1839	0.0134	-0.1339	-0.1710
2.5% span length	-0.0068	-0.0134	-0.0035	0.0105	0.0027	0.0063	0.0134	0.0134
Micronaire value	0.0200	-0.0371	0.0083	-0.0473	-0.0060	-0.0321	0.0302	-0.0304
Budnle strength	-0.0210	0.0760	0.0037	-0.0169	-0.0313	-0.0344	-0.1368	-0.0697
Uniformity ratio	-0.0001	0.0068	0.0187	-0.0022	0.0132	-0.0082	0.0181	-0.0044
Elongation	-0.0081	0.0145	0.0125	-0.0018	-0.0232	-0.0024	0.0034	-0.0045
Lint yield plant⁻¹	-0.0450	-0.0169	-0.3935	-0.0963	-0.7680	-0.5810	0.4433	0.2637
Seed cotton yield plant⁻¹	0.0445	-0.0151	0.5188	0.1244	0.7585	0.8883	-0.4640	-0.0425

Character	Lint index	Ginning out turn	2.5% span length	Micronaire value	Budnle strength	Uniformity ratio	Elongation	Lint yield plant⁻¹
Days to 50 % flowering	-0.0195	0.0038	-0.0103	-0.0147	0.0062	-0.0002	0.0148	0.0041
Plant height	-0.0924	-0.0030	0.0759	-0.1023	0.0836	-0.0580	0.0996	-0.0057
No. of monopodia plant⁻¹	-0.0067	0.0020	-0.0011	-0.0013	-0.0002	0.0091	-0.0049	0.0076
No. of sympodia plant⁻¹	0.0268	-0.0153	0.0458	0.1012	0.0144	-0.0148	0.0095	0.0253
No. of bolls plant⁻¹	-0.1125	0.3919	0.0431	0.0462	0.0968	0.3148	0.4471	0.7313
Boll weight	0.3250	0.0415	0.1436	0.3602	0.1543	-0.2833	0.0679	0.8018
Chlorophyll content	0.0218	-0.0719	0.0537	-0.0590	0.1065	0.1089	-0.0164	-0.1063
Seed index	-0.2946	0.1328	-0.0775	-0.0858	-0.0785	0.0385	-0.0320	0.0915
Lint index	0.4603	0.0892	0.1527	0.0942	0.0912	-0.1165	0.0759	0.0842
Ginning out turn	0.0930	0.4796	0.0519	-0.0560	-0.0491	-0.1409	0.0475	0.3611
2.5% span length	0.0214	0.0070	0.0645	-0.0267	0.0549	-0.0496	-0.0147	0.0116
Micronaire value	-0.0270	0.0154	0.0546	-0.1320	0.0540	-0.0305	-0.0824	-0.0056
Budnle strength	-0.0656	0.0339	-0.2816	0.1353	-0.3308	0.0888	-0.1273	-0.0172
Uniformity ratio	-0.0109	-0.0126	-0.0330	0.0099	-0.0115	0.0429	0.0232	-0.0072
Elongation	-0.0087	-0.0052	0.0120	-0.0331	-0.0204	-0.0287	-0.0530	-0.0121
Lint yield plant⁻¹	-0.1962	-0.8082	-0.1927	-0.0459	-0.0557	0.1794	-0.2459	-1.0734
Seed cotton yield plant⁻¹	0.1141	0.2809	0.1016	0.1904	0.1156	0.0600	0.2091	0.8910

Residual effect =SQRT (1-1.2089).

*Significant at 5% level   **Significant at 1% level   Bold and diagonal values indicate direct effects

RESULTS AND DISCUSSION

The analysis of variance indicated significant differences among the genotypes for all the characters. Genotypic correlation coefficients in general were higher than phenotypic correlation coefficients (Table 1.). Seed cotton yield per plant was significantly and positively correlated with plant height, no. of bolls plant[-1], boll weight, ginning out turn and lint yield plant[-1] at both phenotypic and genotypic levels. Where as only at genotypic level with number of monopodia plant[-1], micronaire value with elongation % indicates that improvement in yield is possible through simultaneous selection for these component characters under hybridization programmes in cotton. Similar results were reported by Kumari Vinodhana *et al.* (2013) and Rumesh Ranjan *et al.* (2014).

Significant and positive correlations at both the levels were also observed between component characters themselves like plant height with number of sympodia plant[-1], seed index, lint index and micronaire value (Kumari Vinodhana *et al.*, 2013 and Chitti *et al.*, 2014), number of monopodia plant[-1] with number of sympodia plant[-1], no. of bolls plant[-1], number of sympodia plant[-1] with no. of bolls plant[-1] and micronaire value (Rajamani *et al.* 2013 and Krishna Mohan, 2011), number of bolls plant[-1] with boll weight, elongation and lint yield plant[-1] (Eswar Rao, 2008), boll weight with seed index, lint index , micronaire value and lint yield plant[-1] (Kumari Vinodhana *et al.*, 2013 and Santosh Kumar *et al.*, 2014), seed index with lint index and micronaire value (Kumari Vinodhana *et al.*, 2013 and Santosh Kumar *et al.*, 2014), lint index with 2.5% span length, micronaire value, bundle strength and lint yield plant[-1] (Rajanna *et al.*, 2011 and Rajamani *et al.* 2013), ginning out turn with lint yield plant[-1] (Krishna Mohan, 2011), 2.5% span length with bundle strength (Kumari Vinodhana *et al.*, 2013 and Santosh Kumar *et al.*, 2014), micronaire value with elongation % (Eswar Rao, 2008), uniformity ratio with elongation % (Krishna Mohan, 2011).

The correlation coefficient estimates mostly indicated inter-relationship of different characters but it did not furnish information on cause and effect. Under such situation path analysis helps the breeder to identify the index of selection. Path coefficient analysis was done in order to study the direct and indirect effects of individual component characters on the dependent variable *i.e.*, seed cotton yield plant[-1]. Study of path coefficients enable the breeders to concentrate on the variables which show high direct effect on seed cotton yield. The genotypic and phenotypic correlation coefficients of seed cotton yield with other yield and fibre quality traits was further partitioned into direct and indirect effects and the results were presented in Table 2 and 3.

The component of residual effect of path analysis in yield and fibre quality traits is 0.2089 at genotypic level and 0.401 at phenotypic level. The lower residual effect indicated that the characters chosen for path analysis were adequate and appropriate.

Path coefficient analysis indicated that number of bolls plant[-1] and boll weight had shown direct positive effect on seed cotton yield plant[-1] at both phenotypic and genotypic levels, lint yield plant[-1] at genotypic level, where as number of sympodia plant[-1], chlorophyll content, lint index and ginning out turn at phenotypic level suggesting that the direct contribution of these different characters to yield would be highly important for formulating an appropriate selection programme as cotton breeding includes several agronomic and fibre traits, whose association may interfere in the selection. These results are in conformity with the findings of Kumari Vinodhana *et al.*, (2013) and Rumesh Ranjan *et al.*, (2014) and Santosh Kumar *et al.*, (2014).

The indirect positive effect on seed cotton yield plant[-1] at both phenotypic and genotypic levels by days to 50% flowering, number of sympodia plant[-1], boll weight, ginning out turn and elongation % with number of bolls plant[-1], plant height, number of bolls plant[-1] and micronaire value with boll weight, number of monopodia plant[-1] and lint yield plant[-1] with number of bolls plant[-1] and boll weight, lint index with boll weight and seed index was observed.

Selection for high seed cotton yield seems to be possible through number of bolls plant[-1], boll weight and lint yield plant[-1] as they exerted high positive direct effect as well as had significant and positive association with seed cotton yield plant[-1].

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