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Research Article

Genetic studies in colour-cotton (*Gossypium hirsutum* L.) genotypes for seed cotton yield and fibre quality traits

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Abstract
The success of plant breeding depends on the existence of genetic variability present in the experimental material. Assessment of the extent and distribution of genetic variation in a crop species is essential in establishing the pattern of diversity and evolutionary relationships. We evaluated 240 colour-cotton genotypes of varying shades of brown and green lint with five white genotypes as checks during Kharif 2016 in Agricultural Research Station, Dharwad Farm, University of Agricultural Sciences, Dharwad using an augmented design. Analysis of variance indicated that there was a significant variation in the experimental material. Ample variability was observed in the experimental material studied for all the characters. Fibre colour exhibited high values of PCV, GCV, heritability and genetic advance as per cent of mean (GAM). It indicated that there was less influence of environment on the expression of colour and selection can be effective based on this trait. Whereas, fibre strength and length exhibited low PCV and GCV values, low heritability coupled with low genetic advance indicating a greater influence of environment on the fibre traits and thus may show low response to selection. Most of the traits studied were negatively associated with the fibre colour indicating the difficulty in the improvement of fibre colour along with other yield-related traits. It is challenging to break the negative association of these traits by transgressive breeding approaches to select for transgressive segregants with high yield along with good fibre colour.

Keywords
Colour-cotton, Variability, Fibre colour

INTRODUCTION

Cotton, the king of fibre, known for its desirable properties and global importance in agriculture is also called 'white gold'. Worldwide, the commercial cotton is almost white linted in all the cultivated species and to an extent, creamy white in *Gossypium barbadense* L. The virgin white colour is stable and will not lose its brightness (Phillip *et al.,* 2006). Cotton with naturally coloured lint, other than white, is commonly referred as Colour-cotton. The early primitive forms of the cultivated species must have been colour linted to dirty white; brown appears to be the basic colour (Narayananan *et al.,* 1996). To date, chemical dyeing is still considered as the only way to colour cotton clothing. After the industrial dye process, it is cheaper to dump the used water dye effluent than to clean and reuse the water. Dye factories across the world are dumping millions of tons of dye effluents into the rivers. In this backdrop, the colour-cotton has an eco-friendly edge over the white cotton. Despite the appeal of naturally coloured cotton as an environment-friendly source of staple fibre, they still occupy only a small global market. Fibre quality is the most important and limiting factor in the genetic improvement of colour-cotton. The coloured fibres are typically lower yielding, shorter and weaker compared with the conventional white fibres (Yuan *et al.*, 2013) and hence are difficult to spin. Knowledge of genetic variation existing in the available breeding material is a prerequisite for any crop improvement program. Assessment of the extent and distribution of genetic variation in a crop species is essential in establishing the pattern of diversity and evolutionary relationships. Identification of natural colour genotypes with stable colour and excellent fibre qualities is important for manufacturing ecological textiles of good quality.

MATERIAL AND METHODS

The present experiment was conducted at the Agricultural Research Station, Dharwad Farm, University of Agricultural Sciences, Dharwad, utilizing 240 natural colour-cotton breeding lines evaluated along with five white linted genotypes as checks *viz.,* Sahana, ARBH-813, MCU-5, Abadhita and RAH-100 in augmented design. Fibre quality characters *viz.,* fibre length, fibre strength, micronaire reading and length uniformity index were analyzed under high volume instrument (HVI) at the regional quality evaluation unit of Central Institute for Research on Cotton Technology (CIRCOT), Dharwad Farm.

The colour strength (K/S) values of the samples were measured by using spectrophotometer. Five readings were recorded for each sample and an average value was calculated, where K is the absorption coefficient and S is the scattering coefficient. Higher the K/S values greater is the colour yield.

$$K/S = \frac{(1-R)^2}{2R}$$

where K/S – Colour strength

R- Reflectance

The genotypic and phenotypic coefficient of variation was computed according to Burton and Devane (1953).

$$\text{Genotypic coefficient of variance (GCV \%)} = \frac{\sqrt{V_g}}{\bar{X}} \times 100$$

$$\text{Phenotypic coefficient of variance (PCV \%)} = \frac{\sqrt{V_p}}{\bar{X}\bar{X}} \times 100$$

V_g = genotypic variance
V_p = phenotypic variance and
$\bar{X}$ = general mean of the character

Heritability in a broad sense was estimated as the ratio of genotypic to the phenotypic variance and expressed in percentage.

$$\text{Heritability } (h^2_{bs}) = \frac{V_g}{V_p} \times 100$$

where,

V_g = genotypic variance
V_p = phenotypic variance

The extent of genetic advance to be expected by selecting five per cent of superior progeny was calculated by using the following formula.

GA = ih² ?

i = intensity of selection (at 5%)
h^2_{bs} = heritability in broad sense
$?_p$ = phenotypic standard deviation

The value of 'i' was taken as 2.06 assuming 5 per cent selection intensity.

Genetic advance over mean was estimated using the following formula

$$GAM\ (\%) = \frac{GA}{\bar{X}} \times 100$$

GA = genetic advance
XX= general mean of the character

Pearson's correlation coefficients for all the characters were estimated by employing the formula of Weber and Moorthy

(1952). Path coefficient analysis was carried out using the simple correlation coefficient to know the direct and indirect effects of the yield components on seed yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959).

RESULTS AND DISCUSSION

A greater amount of genetic variability in the initial stages of a breeding program ensures better and desirable genotypes in the end. Highly significant treatment sum of squares was noticed for all the yield and yield contributing characters *viz.,* days to first flowering, days to 50 per cent flowering, plant height, the number of monopodia per plant, the number of sympodia per plant, the number of bolls per plant, lint index, seed index, ginning outturn and seed cotton yield per plant except for boll weight. This indicated that there was considerable variability among the genotypes and these traits can be relied upon in a crop improvement program.

Table1. Analysis of variance for yield and fibre quality characters in the genotypes of colour-cotton (*G. hirsutum* L.)

Source of variation	df	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
Block (eliminating check + variety)	11	5.05	11.90	91.49	0.66	2.94	6.45	0.03	1.66	0.19	0.33
Entries (ignoring blocks)	244	7.65	11.23*	118.36**	0.35**	7.95**	5.78*	0.19**	20.89**	7.63**	0.78**
Checks	4	20.05*	4.19	492.80**	1.12**	7.05**	4.59*	0.59**	17.27**	0.83**	3.53**
Varieties	239	7.40	11.19**	100.06	0.33**	7.98**	5.80*	0.18**	18.11**	7.69**	0.74**
Checks vs varieties	1	17.52	48.80**	2998.8**	1.39**	5.60	6.30	2.21**	698.67**	20.72**	0.03
Error	44	6.37	6.89	66.14	0.21	1.45	6.00	0.07	1.48	0.16	0.31

Source of variation	df	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}
Block (eliminating check + variety)	11	165.58*	1.38	2.04	0.05	7.03	0.01	0.03	0.161
Entries (ignoring blocks)	244	135.36**	9.12**	10.32**	0.56**	25.31**	0.03**	0.02	5097.55**
Checks	4	572.09**	7.01**	8.16**	0.77**	11.52**	0.04**	0.07**	0617
Varieties	239	123.10**	8.77**	1.98	0.57**	17.97**	0.03**	0.02	2068.22**
Checks vs varieties	1	1316.9**	15.35**	20.13**	0.48	1834.2**	0.08**	1.24**	7493.33**
Error	44	50.30	1.92	1.94	0.14	4.26	0.01	0.02	0.06127

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

X_1 – Plant height (cm)	X_2 - Number of monopodia per plant	X_3 - Number of sympodia per plant	X_4 - Number of bolls per plant
X_5 - Seed index (g)	X_6 - Ginning outturn (%)	X_7 - Lint index (g)	X_8 - Boll weight (g)
X_9 – Days to first flowering	X_{10}- Days to 50% flowering	X_{11}- Seed cotton yield (g)	X_{12}- Fibre colour intensity
X_{13}: Upper Half Mean Length (mm)	X_{14}- Fibre strength (g/tex)	X_{15}-Micronaire value (µg inch^{-1})	X_{16}- Uniformity Index (%)
X_{17}- Maturity Ratio	X_{18}: Elongation Value (%)		

Significant variability was observed for seed cotton yield among the genotypes studied. This trait exhibited a range from 19.00g to 94.70g with a mean of 49.10g. Among the colour linted genotypes, green linted ones exhibited lower yields and medium brown linted genotypes showed higher yields. Seed cotton yield per plant exhibited high PCV values with moderate GCV values with moderate heritability coupled with high GAM indicating a moderate response to selection. Significant variability was observed for ginning outturn among the genotypes. This trait exhibited moderate GCV and PCV values with the narrow difference between them indicating the low influence of the environment. High heritability with high GAM indicates a high response of a character to selection. Results are in accordance with the findings of Singh *et al*. (2009), Pujer *et al*. (2014), Dahiphale *et al.* (2015) and Manjunath Paloti (2016) in white linted cotton. There were no studies in colour-cotton for corroboration.

Table2. Genetic parameters for yield and fibre quality traits in colour-cotton genotypes (*G. hirsutum* L.)

Characters	Mean	Minimum	Maximum	h^2 (bs)	PCV (%)	GCV (%)	GA (%)	GAM (%)
Days to first flowering	67.00	62.00	76.00	0.12	4.01	1.38	0.83	1.24
Days to fifty flowering	73.54	68.00	84.00	0.34	4.39	2.57	2.91	3.97
Plant height (cm)	75.60	50.40	105.80	0.30	12.84	7.02	7.65	10.12
Number of monopodia per plant	1.09	0.00	2.80	0.31	51.74	28.21	0.46	42.55
Number of sympodia per plant	11.44	7.80	19.40	**0.78**	22.67	20.13	5.45	47.17
Number of bolls per plant	12.31	7.00	20.40	0.02	19.62	3.35	0.18	1.51
Seed index (g)	9.45	7.35	11.89	0.54	8.66	6.36	1.16	12.31
Ginning outturn (%)	33.84	18.07	40.86	**0.90**	11.55	10.98	9.31	27.53
Lint index (g)	5.03	2.29	6.47	**0.97**	50.13	49.66	6.51	129.42
Boll weight (g)	4.21	3.00	5.30	0.53	9.66	7.03	0.57	13.53
Seed cotton yield per plant (g)	49.10	19.00	94.70	0.54	21.43	15.82	15.15	30.87
UHML (mm)	22.16	19.10	27.80	0.26	7.31	3.79	1.14	5.19
Fibre strength (g/tex)	23.95	22.20	30.30	0.02	5.86	0.72	0.05	0.23
Micronaire value (µg $inch^{-1}$)	4.02	2.08	5.76	0.72	17.36	14.72	1.32	32.94
Uniformity Index	79.79	70.00	88.30	0.73	4.96	4.28	7.59	9.52
Maturity Ratio (%)	0.75	0.60	0.85	0.74	21.88	18.78	0.32	42.53
Elongation value (%)	5.23	4.70	5.80	0.09	2.64	0.80	0.03	0.64
Fibre colour	31.76	1.394	62.09	**0.98**	31.66	31.65	27.06	85.53

Fibre length and fibre strength are important technological traits that influence the textile industry. The variability observed for these characters was significantly high. These traits exhibited low PCV and GCV values with low heritability coupled with low genetic advance indicating the low influence of environment on the expression of these traits which may lead to low response under selection.The intensity of pigmentation and stability of fibre colour are important parameters in colour-cotton. Ample variability was observed in the experimental material studied. Fibre colour exhibited high values of PCV, GCV, heritability and genetic advance as per cent of mean. There was less influence of the environment on the expression and hence selection based on this trait can be effective. However, no previous studies were found in this area to either corroborate or oppose the current findings.

Table3. Phenotypic correlation coefficients among fibre colour and fibre quality traits in colour-cotton genotypes (*G. hirsutum* L.)

	UHML	FS	Mic	UI	MR	EL	SI	LI	SCY	FC
UHML	**1.000**	**0.931****	**-0.484****	-0.204**	-0.439**	0.406**	0.339**	-0.183**	**-0.232****	**-0.802****
FS		**1.000**	**-0.563****	0.146**	-0.509**	0.354**	-0.012	0.195**	**-0.302****	**-0.820****
Mic			**1.000**	-0.031	-0.058	0.135**	0.031	0.012	0.021	0.260**
UI				**1.000**	-0.191**	0.132**	-0.112*	0.091	**0.447****	-0.457**
MR					**1.000**	-0.163**	0.112**	0.098	0.114	0.270**
EL						**1.000**	0.010	-0.186	0.235**	-0.490**
SI							**1.000**	0.239**	0.034	0.038
LI								**1.000**	0.421**	0.020
SCY									**1.000**	**-0.334****
FC										**1.000**

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

ML: Upper Half Mean Length n) FS: Fibre strength (g/tex) Mic: Micronaire value (µg $inch^{-1}$) UI: Uniformity Index (%)
ł: Maturity Ratio EL: Elongation Value (%) SI: Seed index (g) LI: Lint Index (g)
Y: Seed cotton Yield (g) FC: Fibre colour

The results showed high positive direct effects on yield from micronaire value (0.084), elongation value (0.047), uniformity index (0.043), upper half mean length (0.040), the number of sympodia per plant (0.023), boll weight (0.018) and lint index (0.005). The high R^2 value (0.69) suggests that most of the variability in seed cotton yield was explained by the traits considered in this study. The residual effect (0.56) indicated the environmental effect and requirement of other variables to completely explain the variability in seed cotton yield. Fibre quality traits *viz.,* fibre strength (-0.497) and maturity ratio (-0.040) had negative indirect effects on seed cotton yield. All fibre quality traits exhibited moderate to low indirect effects on seed cotton yield. Similar observations were made by Ashokkumar and Ravikesavan (2010), Naqib *et al.* (2010), Farooq *et al.* (2014), Pujer *et al.* (2014), Dahiphale *et al.* (2015), Latif *et al.* (2015) and Manjunath Paloti (2016) in white cotton.

Table 4. Direct and indirect effects of different characters on seed cotton yield at phenotypic level in colour-cotton

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_1	**0.140****	0.002	0.033**	0.033	-0.012	0.016	0.012**	0.001	-0.001	-0.003	-0.020*	0.005*	-0.019**	0.001
X_2	0.003	**0.189****	-0.013	0.003	0.042**	0.002	0.013**	0.023**	-0.042**	-0.042**	0.007	-0.021**	0.005	-0.039**
X_3	0.005	-0.002	**0.023****	0.005	-0.001	0.001	-0.001	0.001	0.001	0.000	0.002	0.001	0.002	-0.002
X_4	0.140**	0.040	0.079**	**0.585****	0.004	0.078**	-0.002**	0.034**	-0.044**	-0.041**	0.020*	-0.024**	-0.001	-0.087**
X_5	-0.013	0.039	-0.006	0.001	**0.171****	-0.061**	0.003**	0.048**	-0.001	-0.003	-0.021*	0.005**	-0.019**	0.001
X_6	0.016	0.001	-0.001	0.000	-0.051**	**0.139****	0.030**	0.043**	-0.005	-0.066**	0.105**	-0.004**	0.095**	-0.038**
X_7	0.001	0.001	-0.001	0.000	0.001	0.001	**0.005****	0.003	-0.001	0.001	0.001	0.000	0.001	0.001
X_8	-0.001	-0.002	-0.006	0.001	-0.005	-0.006	-0.001	**0.018****	0.002	0.004	-0.020*	0.005**	-0.019**	0.001
X_9	-0.001	-0.009	0.001	-0.003	-0.001	-0.016	-0.007**	-0.004**	**0.040****	0.037**	-0.019*	0.008**	-0.018**	0.016**
X_{10}	0.009	0.011	0.001	0.003	0.001	0.024	0.009**	0.001	-0.040**	**-0.497****	0.028*	-0.007**	0.025**	-0.018**
X_{11}	-0.001	0.003	0.007	0.003	-0.010	0.065**	0.009**	-0.001	-0.041**	-0.047**	**0.084****	-0.003	0.083**	-0.016**
X_{12}	0.000	-0.005	0.008	0.002	0.013	-0.001	0.001	0.001	0.008	0.006	-0.001	**0.043****	-0.003	0.006
X_{13}	0.001	-0.001	-0.004	0.001	0.005	-0.028	-0.004**	-0.001	0.017**	0.029**	-0.040**	0.002	**-0.040****	0.006
X_{14}	-0.008	-0.011	-0.004	0.001	0.001	-0.013	-0.008**	-0.008**	0.019**	0.017*	-0.009	0.006**	-0.007	**0.047****
X_d	0.318	0.279	0.130	0.696	0.150	0.306	0.074	0.186	-0.180	-0.219	0.256	0.065	0.211	-0.196
				R^2 = 0.69							**Residual effect = 0.56**			

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

- Plant height (cm) X_2 - Number of monopodia per plant X_3 - Number of sympodia per plant X_4 - Number of bolls per plant
- Seed index (g) X_6 - Ginning outturn (%) X_7 - Lint index (g) X_8 - Boll weight (g)
– UHML (mm) X_{10} – fibre strength (g/tex) X_{11} – micronaire value (μg $inch^{-1}$) X_{12}- Uniformity index (%)
- Maturity ratio X_{14}- Elongation (%)

Most of the traits studied were negatively associated with the fibre colour indicating the difficulty in improving the fibre colour along with other yield-related traits. Among the fibre quality traits, fibre strength alone can be used as a negative surrogate for indirectly selecting fibre colour as indicated by high negative direct path coefficient value, though the indirect contribution of fibre strength through other variables was negligible. However, no previous studies were found in this area to support the current findings.As most of the traits were negatively associated with fibre colour as suggested by correlation coefficients and path coefficient values, simultaneous improvement of colour and yield is difficult. It is important to break the negative association of these traits by transgressive breeding approaches to select segregants with both high yield and good fibre colour.

In the absence of any meaningful research attempts to improve colour-cotton until now, the present study aims at understanding the dynamics of colour and yield. The results obtained have been encouraging and specific breeding methodologies can now be employed in the genetic improvement of colour-cotton.

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