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Association analysis among agronomic and fiber quality traits in color-cotton (*Gossypium hirsutum*)

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Abstract
Improvement in the seed cotton yield with stable natural Color is an important goal in Color-cotton breeding. Seed cotton yield being a complex quantitative trait is affected by both genetic and environmental factors. Correlation studies pave a role in selection of yield influencing traits and gives an idea how traits are associated with it. We evaluated 240 Color-cotton genotypes with five white genotypes as checks during *kharif* 2016 at the Agricultural Research Station (ARS), Dharwad farm, University of Agricultural Sciences, Dharwad using an augmented design. Analysis of variance indicated that there was significant variation in the experimental material. Seed cotton yield had highly significant and positive correlation with its component traits *viz.,* plant height, number of monopodia per plant, number of sympodia per plant, number of bolls per plant, ginning outturn and boll weight. These traits can be used as surrogate traits for improvement of yield. Fiber color was negatively associated with upper half mean length of fibre, fiber strength, uniformity index and elongation value. It thus seems that improvement of fiber quality traits and improving intensity of pigmentation simultaneously is challenging. Intensity of pigmentation was directly associated with fiber fineness and maturity ratio. Thus, improvement of fiber color retaining other fiber quality traits should be the priority breeding approach in Color-cotton.

Keywords: Color-cotton, correlation, fiber color

Introduction
It is estimated that the elimination of dyeing cotton in textiles can save up to one half of the manufacturing costs and also takes care of the disposal of toxic dye waste which includes heavy metals. Dyes have a hard time adhering to cotton and at least half of the chemicals end up in rivers and in the soil. These chemicals are often highly carcinogenic, toxic and explosive. Commonly used Azo dyes are poisonous, dangerous and highly inflammable. Naturally colored cotton (Color-cotton) is an attractive eco-friendly proposition for the textile industry.
Worldwide, the commercial cotton is almost white (creamy yellow to bright white), white linted cotton in all the four cultivated species and creamy white in *Gossypium barbadense* L. The virgin white color is stable and will not lose its brightness (Phillip *et al.,* 2006) [12]. Cotton with naturally colored lint, other than white, is commonly referred as color-cotton. The early primitive forms of the cultivated species must have been color linted to dirty white; brown appears to be the basic color (Narayananan *et al.,* 1996) [10]. The genotypes and wild species which produce naturally color lint or fuzz are non-spinnable to manufacture eco-friendly fabrics.
Color-cottons are typically grown as the source of fibre for niche textile markets that promote the use of natural colors in textiles. This use has great merit considering the negative environmental impact (Khatri *et al.,* 2015) [6]. Despite the appeal of naturally colored cottons as an environment friendly source of staple fibre, they still occupy only a small global market. Fiber quality is the most important factor limiting the improvement of color-cotton. The colored fibres are typically lower yielding, shorter and weaker compared with conventional white fibres (Yuan *et al.,* 2013) [15]. Lack of rules and criteria for quality classification, natural drift of colored pollen over white cotton and limited range of colors and color unevenness are the other factors which has historically suppressed the growing of color-cotton.
Knowledge on genetic variation existing in the available breeding material is a prerequisite for any crop improvement programme. 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 color-cotton genotypes with stable color and excellent fiber qualities is important for manufacturing eco-friendly textiles of good quality.

Material and methods

The present research was conducted to determine the association between seed cotton yield, yield attributing traits and fiber quality traits. The present experiment was conducted in Agricultural Research Station, Dharwad Farm jurisdiction of University of Agricultural Sciences, Dharwad utilizing 240 color-cotton breeding lines evaluated with five white linted genotypes as checks *viz.,* Sahana, ARBH-813, MCU-5, Abadhita and RAH-100 in augmented design. Fiber quality characters *viz.*, fiber length, fiber strength, micronaire reading and length uniformity index were analysed under high volume instrument (HVI) at Central Institute for Research on Cotton Technology (CIRCOT), regional quality evaluation unit situated at ARS, Dharwad farm. Correlation coefficients were calculated using Pearson's correlation coefficient for all the characters by employing the following formula of Weber and Moorthy (1952).

$$r = \frac{Cov(x,y)}{\sqrt{Var_x, Var_y}}$$

Where,
r = correlation coefficient
Cov (x, y) = variance between the characters x and y
V(x) and V(y) = variances of the characters, x and y
The test of significance for association between characters was done by comparing calculated 'r' values with table 'r' values at (n-2) error degrees of freedom, where n is the number of pairs of observations.

Results and Discussion

Significant treatment mean sum of squares were observed for the eleven quantitative yield traits and six fiber quality traits, indicating considerable amount of variation in all the traits. The material selected for the present investigation was quite appropriate for further genetic analyses (Table 1). The fiber color was characterized in to four different fiber color categories based on the reflectance values. Index score method was applied to classify brown color values. From 5 to 20 were classified as cream or almond color, 20 to 35 as medium brown and values more than 35 were classified as dark brown.

Improvement in the seed cotton yield is an important goal in cotton breeding. Seed cotton yield being a complex quantitative trait is affected by both genetic and environmental factors. Correlation studies give an idea how traits are associated with yield thus paving the way in selection of such traits for yield improvement. Seed cotton yield per plant had significant positive correlation with plant height (0.148), number of monopodia (0.202), number of sympodia (0.212), number of bolls per plant (0.218), ginning outturn (0.518), and boll weight (0.430) and was significantly negatively correlated with the days to fifty per cent flowering (-0.359) (Table 2).

Plant height had positive significant correlation with number of sympodia per plant (0.244), number of bolls per plant (0.239), seed cotton yield (0.148) and it was non-significantly correlated with all other traits. Number of monopodia per plant had positive significant association with seed index (0.224), days to first flowering (0.144), days to fifty per cent flowering (0.150) and seed cotton yield (0.202). Positive significant correlation was noticed between the number of sympodia per plant with number of bolls per plant (0.135) and seed cotton yield per plant (0.218). Seed index had significant positive association with boll weight (0.277) and negative association with ginning outturn (-0.358). Boll weight had positive relationship with ginning outturn (0.312) and seed cotton yield (0.430). Ginning outturn was positively correlated with lint index (0.218) and seed cotton yield (0.518). Days to first flowering had positive relationship with days to fifty per cent flowering (0.689). Similar observations were made by Ashokkumar and Ravikesavan (2010) [2], Naqib *et al*. (2010) [9], Farooq *et al*. (2014) [5], Pujer *et al*. (2014) [13], Dahiphale *et al*. (2015) [4], Latif *et al*. (2015) [7] and Manjunath Paloti (2016) [8].

Fiber color had positive significant correlation with flowering traits *viz.,* days to first flowering (0.133) and days to fifty per cent flowering (0.200). Plant height (-0.298), ginning outturn (-0.122), boll weight (-0.130) and seed cotton yield per plant (-0.334) were significantly and negatively associated with fiber color (Table 2). This showed that, as the intensity of pigmentation increased the yield potential of the genotype decreased, pointing towards a possible negative pleiotropic effect of fiber color on seed cotton yield. However, no previous studies were found in this area to either corroborate or oppose the current findings.

Table 1: Analysis of variance for yield and fiber quality traits in breeding lines of color-cotton genotypes (*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

X1 – Plant height (cm) X2 - Number of monopodia per plant X3 - Number of sympodia per plant X4 - Number of bolls per plant
X5 - Seed index (g) X6 - Ginning outturn (%) X7 - Lint index (g) X8 - Boll weight (g)
X9 – Days to first flowering X10- Days to 50% flowering X11- Seed cotton yield (g) X12- Fiber color
X13: Upper Half Mean Length (mm) X14- Fiber strength (g/tex) X15-Micronaire value (µg inch-1) X16- Uniformity Index (%)
X17- Maturity Ratio X18: Elongation Value (%)

Table 2: Phenotypic correlation coefficients among yield and its component traits in *G. hirsutum*

	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_1	1.000	0.012	0.244**	0.239**	-0.07	0.012	0.115	0.070	-0.040	-0.030	0.148**	-0.298**
X_2		1.000	-0.071	0.068	0.224**	0.127	0.011	0.071	0.144**	0.151**	0.202**	0.024
X_3			1.000	0.135**	0.001	-0.008	0.034	-0.024	-0.002	0.051	0.212**	-0.081
X_4				1.000	0.001	-0.050	0.138**	-0.041	0.010	-0.001	0.218**	-0.082
X_5					1.000	0.277**	-0.358**	0.023	0.062	-0.051	0.034	0.038
X_6						1.000	0.312**	0.067	-0.087	0.014	0.430**	-0.122**
X_7							1.000	0.218**	0.039	0.001	0.518**	0.020
X_8								1.000	-0.036	-0.032	0.035	-0.130**
X_9									1.000	0.689**	-0.036	0.133**
X_{10}										1.000	-0.035	0.200**
X_{11}											1.000	-0.334**
X_{12}												1.000

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

X1 – Plant height (cm) X2 - Number of monopodia per plant X3 - Number of sympodia per plant X4 - Number of bolls per plant
X5 - Seed index (g) X6 - Ginning outturn (%) X7 - Lint index (g) X8 - Boll weight (g)
X9 – Days to first flowering X10- Days to 50% flowering X11- Seed cotton yield (g) X12- Fiber color

Table 3: Phenotypic correlation coefficients among fiber color and fibre quality traits in natural color-cotton lines *G. hirsutum*

	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

UHML: Upper Half Mean Length (mm) FS: Fiber strength (g/tex) Mic: Micronaire value (µg inch-1) UI: Uniformity Index (%)
MR: Maturity Ratio EL: Elongation Value (%) SI: Seed index (g) LI: Lint Index (g)
SCY: Seed cotton Yield (g) FC: Fiber color

Association studies with fiber quality traits

The trait seed cotton yield per plant had positive significant association with uniformity ratio (0.441) and lint index (0.072) where as it had negative significant relationship with upper half mean length (-0.232), fiber strength (-0.302) and elongation value (-0.235). Fiber length had positive correlation with fiber strength (0.931), elongation value (0.406) seed index (0.339) whereas negative association with micronaire value (-0.484), uniformity ratio (-0.207), maturity ratio (-0.439) and lint index (-0.183) (Table 3). Similar observations of negative significant correlation of seed cotton yield in white cotton with these traits were made by Ashokkumar and Ravikesavan (2010) [2], Bayyapu Reddy *et al*. (2015) [3] and Manjunath Paloti (2016) [8].

Positive significant relationship was observed between fiber strength and uniformity ratio (0.146) whereas it had negative association with micronaire value (-0.563), maturity ratio (-0.509), lint index (-0.191) and seed cotton yield (-0.302). Similar results were reported by Ashokkumar and Ravikesavan (2010) [2], Patil Malagouda *et al*. (2014) [11] and Amjid *et al*. (2016) [1]. Micronaire value had positive correlation with elongation value (0.135).

Uniformity ratio had positively associated with elongation value (0.135) and seed cotton yield (0.447) whereas, it had a negative relationship with maturity ratio (-0.191). Negative relationship was observed between maturity ratio and elongation value (-0.163). Seed index was positively correlated with lint index (0.239) whereas; lint index had positive relation with seed cotton yield per plant (0.072).

Significant higher negative correlation was observed between fiber color and upper half mean length (-0.802), fiber strength (-0.820), uniformity index (-0.457) and elongation value (-0.490). Micronaire value (0.260) and maturity ratio (0.270) had significantly positively associated with fiber color. It was learnt that, as the intensity of pigmentation increased there was a compromise with both the fiber length and strength. Therefore improvement of fiber color, retaining other fiber quality traits becomes a priority breeding approach in color-cotton.

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