Original Research Article

<https://doi.org/10.20546/ijcmas.2018.711.109>

Multi-Environment Evaluation to Identify Promising Germplasm Lines for Economically Important Traits in *G. hirsutum* Cotton

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ABSTRACT

Our objective was to evaluate *G. hirsutum* cotton lines, which includes indigenous, exotic collection, released varieties and lines developed from different breeding strategies were evaluated in alpha lattice designs with two replications along with five standard *G. hirsutum* check varieties viz., Sahana, Surabhi, MCU 5, DS 28 and ARBH 813 for yield and fibre quality traits. The analysis of variance revealed the presence of significant differences among genotypes and recorded wide range of variations for all the characters over environments. EC296596 (2263 Kg/ha), 128333-Acala-44 (2258 Kg/ha) and 543416A03N132 (2250 Kg/ha) recorded significantly higher seed cotton yield than superior check, ARBH 813 (1894 Kg/ha). CPD-420, FQT-38, CPD-2011, AKA-8828, DRC-305 and CPD-443 recorded higher ginning outturn (>38 percent) with high boll weight (>4.0g), more bolls (>15.0) and more fruiting points (>35). HAG-1055, HLS-321729, AK-23B, 543416A03N132, 126663, FQT-38 and 54335402A015 recorded high seed index with ginning outturn (>37 percent), boll weight (4.0g), more bolls (>14.0) and fruiting points (>35.0), moderate height (>95 cm to 105 cm). Five germplasm lines viz., FQT-21 (31.8 mm), IC356874 (30.9 mm), ADB-39 (30.9 mm), CPD-437 (30.0 mm) and EC559012 (30.0 mm) with higher fiber strength (23.2 to 24.7 g/tex) and on par with ARBH 813 for seed cotton yield (1555 to 1966 Kg/ha). These germplasm collections represent a valuable resource for improving seed cotton yield and fiber quality in cotton.

Keywords

Gossypium hirsutum,
Germplasm, Genetic
variability, Genetic
diversity

Article Info

Accepted:
10 October 2018
Available Online:
10 November 2018

Introduction

Cotton is one of the most important commercial crops which occupied importance from historic days. It is an industrial commodity of worldwide importance.

It occupies the place of pride in Indian agriculture and economy by earning valuable foreign exchange. It is primarily used in textile industries providing highest employment

during production, processing, spinning, weaving and marketing throughout the world.

Germplasm is the genetic source material used by plant breeders to develop new cultivars and one of the consequences of successful plant breeding can be increased erosion or reduction in genetic variability for the crop undergoing selection. There is also a danger that valuable genetic resources may be lost to future breeding programs as the areas of genetic

diversity are developed and as agriculture becomes more intensified (Stoskopf *et al.*, 1993). As a result, breeders need to effectively manage their breeding populations to preserve adequate genetic variation so that future improvements through selection can occur. Proper management of germplasm resources by the breeder includes introducing new germplasm resources on a regular basis to develop new recombinants and hence increase genetic variability. One relevant way to have cotton germplasm information available for breeding purposes is through the evaluation of the existent, yet uncharacterized material. Characters is likely to vary according to the environment in which the genotype is being cultivated, it would therefore, be worthwhile to identify the attributes controlling productivity to suite particular locality.

As mentioned, cotton is natively a crop adapted to tropical and subtropical climates. A shift in the climatic adaptation of the plant has been necessary to enable its successful cultivation in more temperate environments. Germplasm screening for useful characteristics is important for making information available of yet uncharacterized material. The rapid advances in spinning technology in recent decades resulted in increasingly new demands concerning fiber properties. The adoption of new spinning methods, the advances in the traditional spinning process and the higher consumer demands call for extensive research and improvement of the raw material to keep pace with the current quality requirements of the spinning industry. The main objective of this study was to evaluate 320 cotton germplasm lines for both agronomic and fiber characteristics.

Materials and Methods

In the present study a total of 320 germplasm of *G. hirsutum* lines which includes

indigenous, exotic collection, released varieties and lines developed from different breeding strategies with five checks viz., Sahana, Surabhi, MCU 5, DS 28 and ARBH 813 available at Agricultural Research Station, Dharwad Farm were evaluated in alpha lattice designs with two replications. Each replication was subdivided into 16 blocks and each block containing 20 entries representing five environments of two different zones of Karnataka viz. Agricultural Research Station, Dharwad Farm, Institute of organic farming, Dharwad (Zone No. 8) and Agricultural Research Station, Bagalakot (Zone No. 3) under the jurisdiction of University of Agricultural Sciences, Dharwad. Data on seed cotton yield, yield components and fiber quality traits were recorded. The observations on five plants viz., Plant height (cm), No. of monopodia, No. of sympodia, No. of bolls, No. of fruiting points, Boll weight (g), Ginning outturn (%), Seed index (g), Lint index (g) and Seed cotton yield (Kg/ha). The fibre quality parameters included 2.5% span length, fiber strength, micronaire reading and length uniformity index were analyzed under HVI (high volume instrument) at Central Institute for Research on Cotton Technology (CIRCOT), regional quality evaluation unit situated at ARS, Dharwad farm. The observations on four fiber quality traits of 320 germplasm lines were recorded for two environments (E3-ARS, Dharwad farm and E5- ARS, Bagalkot). Phenotypic data were analyzed using REML procedure (Residual Maximum Likelihood) implemented in Cropstat 7.2 software. The least mean squares obtained after removing the block effects were used in further analysis. Variance components were calculated by fitting a linear mixed model to multi-environment data. The data was subjected to randomized complete block design (RCBD) analysis and analyzed using software, Windostat version 9.1 and frequency distribution curves obtained using SPSS version 16.0 software.

Results and Discussion

Germplasm screening for useful characteristics is important for making information available of yet uncharacterized material and has served as a major resource in conjugation with suitable breeding strategies for continuous improvement for yield and fibre quality in cotton. The mean sum of squares for yield traits in 320 *G. hirsutum* cotton germplasm evaluated in five environments is presented in Table 1. The analysis of variance indicated presence of significant variability among the germplasm lines for all yield traits. The data on mean and range for yield traits are presented in Table 2 and 3 represent performance of *G. hirsutum* check varieties. Frequency distribution of germplasm lines was normal for yield and fibre quality traits (Fig. 1).

Plant height is the important trait in determining the plant architecture suggesting its importance in high density planting and for mechanical harvesting. Wide range of variations for plant height over five environments was recorded. On an average, plant height was highest in PSHEC-15 (121.4 cm) followed by SEC-6 (118.3 cm), EC479 (118.0 cm) and 543364A02N46 (114.8 cm), it was 10% more height and statistically on par with the tallest check, Surabhi (103.7cm) and among the different environments the E5 environment recorded highest plant height (117.4 cm) with wide range of variation 81.0 cm to 174.9 cm respectively. On the contrary the line IC356780 (71.5 cm) was dwarf than check, MCU 5 (86.1 cm) a dwarfest among checks. Tuteja *et al.*, (2006) and Verma and Tuteja (2008) also observed wide range of variations for plant height in cotton.

Monopodium is a main branch of cotton plant present at bottom varying from zero to four. This branch provides support to plant preventing from lodging in intensive method

of cultivation with wider row spacing. Plants with higher monopodia are generally robust having more number of sympodia and also having sympodia on monopodia to produce higher yields. In present study the highest number of monopodia was recorded by the line IC357196 (2.89) and is on par with the best check ARBH 813 (2.40). Whereas, in contrast, looking to shortage of labour, identification and utilization of germplasm lines with lower monopodia or zero monopodia to develop variety for mechanical harvesting is necessary. The present study identifies the genotypes with lowest number of monopodia, IC358249 (0.74) followed by genotypes IC358249 (0.74), FQT-2 (0.76), GISV-272 (0.77), EC560401 (0.80), EC560392 (0.88), PVK-Rajat (0.89), FQT-35 (0.91), PS-20-2-1 (0.92), EC560399 (0.99) and CPD-448 (0.99), which was significantly lower than check variety Sahana (1.87) over five environments which would resulted in cultivation for high density planting and suitable for machine harvesting and they may be suitable lines in breeding program for less or zero monopodial plants. Krishnadoss and Kadambavanasundaram (1997) have seen 1.7 monopodia branches. Manjula *et al.*, (2004) observed 4.0 monopodia in *G. herbaceum* genotypes. Tuteja *et al.*, (2006) recorded 4.77 monopodia per plant. Nagaraj *et al.*, (2008) noticed 2.15 of monopodia in elite germplasm lines of cotton.

The braches which bear squares and bolls are sympodia and hence directly influence the seed cotton yield. Normally a cotton plant can have around 5 to 25 sympodial branches. In our study, the variability observed for number of sympodia was ranging from 10.3 to 20.5. Seven germplasm lines have recorded 15% more sympodia than superior check, ARBH 813 (17.1). In the present study the germplasm line RDT-32 (10.3) followed by 16 germplasm lines recorded lowest number of sympodia and on par with inferior check MCU 5 (13.4) with

mean of 16.1 over five environments which suggest that they were compact in nature and suitable for dense cropping and machine harvesting.

Krishnadoss and Kadambavanasundaram (1997) reported up to 20.9 and 21.0 sympodia in direct and reciprocal cross of tetraploid interspecific crosses. Verma and Tuteja (2008) have seen 65.10 sympodia per plant. Nagaraj *et al.*, (2008) recorded 16.10 sympodia branches. Patel *et al.*, (2009) observed 23-44 sympodia in upland cotton genotypes

The number of bolls is an important trait for the genotype which determines its yielding ability. In the present study, mean value recorded for number of bolls across five environments and all genotypes was 13.7 and only one germplasm line NO-15 (21.2) was recorded higher number of bolls over the superior check ARBH 813 (20.3). Genotypes like CPD-824, ARB-08-822, 126663, NO-4 and RAH-110 recorded more number of bolls (>17) with height more than >100 cm and more monopodia (>1.6), sympodia (>16.0). While, the line EC138566 recorded lowest number of bolls which was significantly lesser than inferior check, Sahana (12.6) followed by eight germplasm lines recorded less than 10 bolls and their seed cotton yield per hectare were also low (<1500 Kg/ha). The mean number of bolls of 13.0 (E1), 10.2 (E2), 14.82 (E3), 15.13 (E4), 15.43(E5) with wide range of variation from 2.7 to 21.4 (E1), 0.4 to 31.1 (E2), 7.2 to 26.0 (E3), 7.0 to 23.7 (E4) and 8.3 to 22.8 (E5). About 35.3 bolls per plant were observed by Meena *et al.*, (2006) in upland cotton genotypes. Tuteja *et al.*, (2006) noticed up to 42 bolls per plant. Nagaraj *et al.*, (2008) recorded 16.4 bolls per plant in elite germplasm lines of upland cotton. Baig *et al.*, (2009) noticed 38.07 boll loads per plant.

Fruiting points are the reproductive organs, it depicts potential of plant to bear the flower buds which determines the yielding ability of

genotype. Some of these may drop or dry up because of environmental conditions like poor nutrition or pest attack. In present study, wide range of variation was observed for number of fruiting points from 26.0 to 63.3 and two germplasm lines have recorded more than 20 percent fruiting points over superior check, ARBH 813 (50.7). Among these lines RDT-2 recorded highest fruiting points (63.3) but it exhibited poor yield (1038Kg/ha) followed by 54335402A015 (62.9) which recorded 14% higher yield (2160 Kg/ha) than superior check, ARBH 813 (1894 Kg/ha). Genotypes like CPD-824, ARB-08-822, 126663, CA-105, HAGH-148, HBS-148 and CPD-437 have recorded more number of bolls, fruiting points with more monopoda and sympodia.

Whereas, EC560391 (26.0) followed by 21 germplasm lines have recorded lower number of fruiting points than inferior check, Surabhi (29.9). The range of variation observed for fruiting points was 13.8 to 96.3, 15.8 to 98.3, 20.8 to 54.1, 16.5 to 47.7, 29.2 to 67.4 with the mean values 40.2, 39.2, 36.5, 27.9, 48.1 in E1, E2, E3, E4 and E5 environments.

The lines with big bolls are preferred because of ease in hand picking. It also helps in reducing cost and time involved in manual harvesting. In the present study, over five environments, highest boll weight was recorded by two germplasm lines CPD-431 (5.23g) and IC356874 (5.13g) followed by 23 germplasm lines recorded more than 15 percent and 10 percent high boll weight over the superior check, DS 28 (4.45g) respectively. CPD-431 and IC356874 recorded 43.8 percent and 19.1 percent higher seed cotton yield than check DS 28 (1305 Kg/ha) respectively. However, the line RS-810-SG NR (3.12g) recorded significantly lower boll weight than Surabhi (3.78g), an inferior check. The mean value of 4.35g (E1), 3.75g (E2), 4.40g (E3), 4.11g (E4) and 4.52g (E5) exhibited by this trait with wide range of

variation from 2.98g to 6.74g (E1), 2.58g to 5.05g (E2), 2.80g to 6.10g (E3), 2.73g to 5.79g (E4), and 3.15g to 6.43g (E5). Palomo and Davis (1983) observed 6.46 g boll weight in interspecific F_1 s of tetraploid cottons. Meena *et al.*, (2006) observed 3.8 g boll weight in upland cotton germplasm lines. Tuteja *et al.*, (2006) recorded 3.32 g boll weight.

Ginning outturn depicts the potential of genotype to yield lint which is raw material for textile industry. Hence genotype with high ginning outturn is considered to be good. The lines with high ginning outturn and high seed cotton yield are preferred by breeder in order to maintain interest of farmers and textile industry (ginning factories). Four germplasm lines viz., CPD-460 (40.23 percent), NH-2211 (39.92 percent), EC560430 (39.84 percent) and CPD-423 (39.53 percent) recorded more than 5.0 percent higher ginning outturn with 24.44 percent (1624 Kg/ha), 10.88 percent (1447 Kg/ha), 36.7 percent (1784 Kg/ha) and 26.05 percent (1645 Kg/ha) higher yield than DS 28 (37.59 percent ginning outturn and 1305 Kg/ha seed cotton yield) respectively.

CPD-420, FQT-38, CPD-2011, AKA-8828, DRC-305 and CPD-443 have recorded higher ginning outturn (>38 percent), with high boll weight (>4.0g), more bolls (>15.0) and more fruiting points (>35). Whereas, FQT-21 (30.05 percent) recorded significantly lower than inferior check, Surabhi (34.56 percent) over five environments.

The range of variation observed for this trait was from 25.31 to 42.46 percent, 28.50 to 41.04 percent, 29.82 to 40.89 percent, 28.75 to 40.75 percent, and 30.22 to 40.32 percent with the mean value of 36.01 percent, 36.53 percent, 36.76 percent, 35.91 percent, and 36.60 percent and in E1, E2, E3, E4 and E5 respectively. Krishnadoss and Kadambavanasundaram (1997) recorded 30.7

per cent ginning outturn. Tuteja *et al.*, (2006) recorded 34.3 per cent ginning outturn. Verma and Tuteja (2008) have seen 34.75 per cent ginning outturn in genotypes of upland cotton developed using different cytoplasmic sources. Nagaraj *et al.*, (2008) observed 37.14 per cent ginning outturn in elite germplasm lines of upland cotton.

The relationship between seed index and seed cotton yield is complex, as large seeds with more surface area can bear more number of fibers, but at the same time the total available area for number of fiber decreases as seed index increases to high or too low. Hence moderate seed index about 8 to 10 g is desirable to achieve higher seed cotton yield and ginning outturn.

The variation observed for seed index was from 6.6g to 12.15g. On an average over five environments, the genotype IC356874 (12.15g) recorded more than 30.33 percent of seed index which was significantly higher than best check, Sahana (9.33g) followed by eight germplasm lines. Germplasm lines like HAG-1055, HLS-321729, AK-23B, 543416A03N132, 126663, FQT-38 and 54335402A015 have recorded high seed index with ginning outturn (>37 percent), boll weight (4.0g), more bolls (>14.0), fruiting points (>35.0) and moderate height (>95 cm to 105 cm).

Whereas Tiny-boll (6.60g) showed low seed index and on par with inferior check *i.e.* ARBH 813 (7.59g). The range of variation exhibited in different environments was 6.35 to 14.35, 4.15 to 11.65g, 6.75 to 12.5g, 6.25 to 12.75g, 6.50 to 12.00g with the mean values of 10.73, 7.6, 9.23, 8.63 and 8.69g in E1, E2, E3, E4 and E5 respectively. Palomo and Davis (1983) reported 14 g seed index. Meena *et al.*, (2006) recorded 10.8 g in upland cotton germplasm lines. Bourland and Jones (2009) recorded seed index of 11.1 g.

Fig. 1: Frequency distribution of yield, yield related traits and fiber quality traits of germplasm lines

Fig. 1: Contd...

Fig. 1: Contd...

Table.1 Pooled analysis of variance for yield and yield component traits in cotton germplasm lines

Source of variation	Location	Df	Plant height (cm)	No. of monopodia	No. of sympodia	No. of bolls	No. of fruiting points	Boll weight (g)	Ginning Outturn (%)	Seed index (g)	Lint index (g)	SCY (Kg/ha)
Replications	E1	1	325.3**	0.0048	7.14	0.009	152.0	0.046	2.40	0.145	0.803*	20976
	E2		213.2*	0.002	5.02	0.770	192.2	0.033	23.27	0.039	0.00001	27079*
	E3		384.2*	0.013	12.43	71.95**	16.13	0.197*	8.62	0.044	0.820	175363
	E4		119.8	0.205	2.22	2.55	50.12	0.175	6.02	0.791	1.135*	36060
	E5		219.3	0.157	30.27	2.37	58.68	0.246	12.60	0.308	0.274	86118
Genotypes	E1	319	499.3**	0.4119**	22.56**	14.70**	68.8**	0.823**	19.45**	5.477**	2.790**	894987**
	E2		181.8**	0.9639**	49.05**	13.40**	84.3**	0.491**	13.98**	2.564**	1.233**	74889**
	E3		255.6**	0.638**	13.76**	23.12**	59.19**	0.653**	9.02**	1.862**	0.766**	734885**
	E4		289.0**	0.467**	9.78**	14.07**	57.04**	0.576**	9.51**	2.002**	0.774**	239649**
	E5		405.5**	0.721**	22.07**	14.70**	87.37**	0.815**	7.85**	1.629**	0.701**	355578**
	pooled		688.03**	1.357**	34.07**	35.54**	250.2**	1.136**	26.78**	4.74**	2.11**	788812**
Environment		4	432930**	82.66**	23803**	3022.5*	33706*	59.05**	90.25**	838.1**	245.6**	252940482**
G X E interaction		1276	403.02	0.4615	20.793	18.62	176.6	0.556	8.26	2.198	1.039	377794
Error	E1	319	162.7	0.0517	4.70	1.19	24.20	0.231	8.48	0.763	0.130	37793
	E2		51.14	0.0519	10.84	3.20	19.04	0.124	5.82	0.651	0.047	4211
	E3		82.9	0.103	3.381	5.49	18.75	0.05	2.34	0.332	0.240	85708
	E4		89.6	0.065	3.342	5.78	21.33	0.042	4.05	0.264	0.261	22266
	E5		185.9	0.103	7.999	5.58	15.59	0.086	3.27	0.241	0.195	27823
	Pooled	1595	114.84	0.0752	6.054	4.25	42.58	0.151	2.39	0.451	0.175	35560

*, ** significant at 5% and 1% levels respectively.

E1-ARS, Dharwad (2011), E2- ARS, Dharwad (2012), E3 – ARS, Dharwad (2013), E4-MARS, Dharwad (2013) and E5 – ARS, Bagalkot (2013)

ARS- Agricultural research Station, MARS-Main Agricultural Research Station.

Table.2 Mean and range for different traits in *G. hirsutum* germplasm lines evaluated in five environments

	Season	Plant height (cm)	Number of monopodia	Number of sympodia	Number of bolls	Number of fruiting points	Boll weight(g)	Ginning Outturn (%)	Seed index (g)	Lint index (g)	SCY (Kg/ha)
Mean	E1	94.6	1.32	12.1	13.0	40.2	4.35	36.01	10.73	6.05	1804
	E2	72.3	1.98	26.1	10.2	39.2	3.75	36.53	7.60	4.39	556
	E3	93.5	1.71	13.5	14.8	36.5	4.40	36.76	9.23	5.37	2250
	E4	101.4	1.30	11.2	15.1	27.9	4.11	35.91	8.63	4.84	1312
	E5	117.4	2.07	17.5	15.4	48.1	4.52	36.60	8.69	5.02	1532
	Pooled	95.8	1.67	16.1	13.7	38.4	4.23	36.36	8.98	5.14	1491
Min.	E1	26.3	0.17	4.8	2.7	13.8	2.98	25.31	6.35	2.21	412
	E2	41.1	0.46	8.6	0.4	15.8	2.58	28.50	4.15	2.15	255
	E3	58.7	0.30	8.1	7.2	20.8	2.80	29.82	6.75	3.40	675
	E4	57.4	0.20	5.2	7.0	16.5	2.73	28.75	6.25	2.97	539
	E5	81.0	0.45	11.0	8.3	29.2	3.15	30.22	6.50	3.06	614
	Pooled	71.5	0.74	10.3	8.1	26.0	3.12	30.05	6.60	3.64	770
Max.	E1	142.5	3.13	21.9	21.4	96.3	6.74	42.46	14.35	10.02	3460
	E2	104.3	4.33	41.3	31.1	98.3	5.05	41.04	11.65	7.59	1414
	E3	131.5	3.70	21.4	26.0	54.1	6.10	40.89	12.50	7.42	3874
	E4	135.8	2.95	17.6	23.7	47.7	5.79	40.75	12.75	7.26	2414
	E5	174.9	3.80	35.1	22.8	67.4	6.43	40.32	12.00	6.74	3314
	Pooled	121.4	2.89	20.5	21.2	63.3	5.23	40.23	12.15	6.95	2263
CD at 95%	E1	25.10	0.45	4.27	2.15	9.68	0.95	5.73	1.72	0.71	382.48
	E2	14.07	0.45	6.48	3.52	8.58	0.69	4.75	1.59	0.43	127.67
	E3	17.91	0.63	3.62	4.61	8.52	0.44	3.01	1.13	0.96	575.98
	E4	18.62	0.50	3.60	4.73	9.09	0.40	3.96	1.01	1.01	293.58
	E5	26.82	0.63	5.56	4.65	7.77	0.58	3.56	0.97	0.87	328.17
	Pooled	20.51	0.53	4.70	3.93	8.73	0.61	4.20	1.28	0.79	341.58
CD at 99%	E1	33.05	0.59	5.62	2.83	12.75	1.25	7.55	2.26	0.93	503.77
	E2	18.53	0.59	8.53	4.64	11.31	0.91	6.25	2.09	0.56	168.16
	E3	23.59	0.83	4.76	6.07	11.22	0.58	3.96	1.49	1.27	758.64
	E4	24.53	0.66	4.74	6.23	11.97	0.53	5.21	1.33	1.32	386.67
	E5	35.33	0.83	7.33	6.12	10.23	0.76	4.69	1.27	1.14	432.24
	Pooled	27.01	0.70	6.20	5.18	11.50	0.81	5.53	1.69	1.05	449.89
CV (%)	E1	13.48	17.23	17.92	8.39	12.24	11.05	8.09	8.14	5.96	10.78
	E2	9.89	11.51	12.61	17.54	11.13	9.39	6.60	10.62	4.94	11.67
	E3	9.74	18.77	13.62	15.83	11.86	5.08	4.16	6.24	9.12	13.01
	E4	9.34	19.61	16.32	15.92	16.55	4.99	5.60	5.95	10.56	11.37
	E5	11.61	15.50	16.16	15.34	8.21	6.49	4.94	5.65	8.80	10.89
	Pooled	10.81	16.52	15.33	14.60	12.00	7.40	5.88	7.32	7.87	11.54

E1-ARS, Dharwad (2011), E2- ARS, Dharwad (2012), E3 – ARS, Dharwad (2013), E4-MARS, Dharwad (2013) and E5 – ARS, Bagalkot (2013)

Table.3 Performance of *G. hirsutum* check lines varieties

	Season	Plant height (cm)	Number of monopodia	Number of sympodia	Number of bolls	Number of fruiting points	Boll weight(g)	Ginning Outturn (%)	Seed index (g)	Lint index (g)	SCY (Kg/ha)
Sahana	E1	101.0	1.76	13.1	12.4	23.9	4.19	36.13	9.54	5.43	1625
	E2	62.2	1.81	17.2	6.1	22.4	4.00	35.00	7.35	3.97	364
	E3	103.5	1.90	13.3	16.6	37.8	4.29	38.80	10.25	5.74	2498
	E4	112.2	1.50	15.1	14.1	29.0	3.69	36.08	9.75	5.51	1350
	E5	121.5	2.40	16.3	13.9	40.4	4.55	37.89	9.75	5.95	2256
	Mean	100.1	1.87	15.0	12.6	30.7	4.14	36.78	9.33	5.32	1619
Surabi	E1	104.0	2.02	13.8	14.3	25.7	3.83	34.49	9.04	4.78	1708
	E2	69.2	1.81	23.2	12.5	24.2	2.98	34.76	7.35	3.93	848
	E3	106.2	2.10	12.3	13.8	32.0	3.94	34.73	9.75	5.19	2607
	E4	114.9	1.70	14.1	16.1	23.2	3.48	32.98	9.25	4.55	1464
	E5	124.2	3.05	15.3	16.1	44.6	4.68	35.83	8.75	4.89	1881
	Mean	103.7	2.14	15.7	14.6	29.9	3.78	34.56	8.83	4.67	1702
MCU 5	E1	88.1	1.94	14.2	14.2	42.0	3.94	36.62	7.68	4.49	1409
	E2	77.7	2.06	26.3	14.8	45.0	3.44	35.41	7.05	3.88	581
	E3	79.4	1.80	8.1	12.2	28.2	4.06	38.54	8.50	5.34	1841
	E4	88.0	1.40	7.4	14.5	19.3	3.49	36.01	8.00	4.49	1461
	E5	97.4	2.30	11.0	14.5	40.8	4.40	34.96	7.00	3.77	1739
	Mean	86.1	1.90	13.4	14.0	35.0	3.87	36.31	7.65	4.39	1406
DS 28	E1	92.1	1.97	15.1	14.7	36.5	4.47	37.25	8.18	4.84	1288
	E2	58.9	1.37	19.7	14.2	33.0	3.81	39.19	6.05	3.92	753
	E3	92.8	2.20	12.2	16.1	35.3	4.90	37.63	9.50	5.73	1568
	E4	101.4	1.80	13.0	11.1	26.4	4.11	36.95	8.75	5.13	1060
	E5	110.8	3.20	15.1	13.4	47.9	4.98	36.93	8.25	4.84	1859
	Mean	91.2	2.11	15.0	13.9	35.8	4.45	37.59	8.15	4.89	1305
ARBH 813	E1	97.5	2.39	16.1	20.7	67.3	4.31	37.16	7.44	4.40	1867
	E2	62.5	2.59	26.9	16.5	63.8	3.77	38.74	6.75	4.28	636
	E3	96.8	2.30	14.3	23.9	39.6	4.79	37.65	8.25	5.01	3127
	E4	105.5	1.90	11.1	18.9	30.8	4.27	35.27	7.75	4.25	1692
	E5	114.8	2.80	17.3	21.2	52.2	4.48	37.86	7.75	4.73	2150
	Mean	95.4	2.40	17.1	20.3	50.7	4.32	37.33	7.59	4.53	1894

E1-ARS, Dharwad (2011), E2- ARS, Dharwad (2012), E3 – ARS, Dharwad (2013), E4-MARS, Dharwad (2013) and E5 – ARS, Bagalkot (2013)

Table.4 Pooled analysis of variance for fiber traits in germplasm collection evaluated during 2013 in two environments

Source of variation	Location	df	2.5% Span length (mm)	Uniformity ratio (%)	Micronaire (g/in)	Tenacity (g/tex)
Repliation	E3	1	0.0015	0.225	0.007	0.324
	E5	1	2.50	0.126	0.018	0.306
Genotypes	E3	319	9.29**	4.926**	0.41**	4.261**
	E5		7.584**	4.536**	0.326**	3.219**
	Pooled		13.01**	6.288**	0.517*	4.729**
Environment		1	323.08**	100.1**	1.444**	23.05**
Error	E3	319	0.0015	1.04	0.048	1.187
	E5		1.095	2.214	0.034	0.466
	Pooled		3.866	3.17	0.219	2.75

E3 – ARS, Dharwad and E5 – ARS, Bagalkot

*, ** significant at 5% and 1% levels respectively

Table.5 Mean, range and performance of different *G. hirsutum* check lines for fiber traits evaluated during 2013 at two locations

	Locations	2.5% Span length (mm)	Uniformity ratio (%)	Micronaire (g/in)	Tenacity (g/tex)
Mean	E3	28.5	47.5	3.97	21.98
	E5	27.5	48.0	3.99	21.68
	Mean	28.0	47.8	3.98	21.83
Min	E3	22.5	40.0	2.20	18.40
	E5	22.8	44.0	2.90	18.50
	Mean	23.2	44.0	2.85	18.45
Max	E3	36.3	53.0	5.10	26.00
	E5	33.4	52.0	5.20	26.80
	Mean	33.2	52.5	4.85	24.85
Sahana	E3	29.5	47.0	3.30	21.10
	E5	29.3	47.0	3.50	22.10
	Mean	29.4	47.0	3.40	21.60
Surabhi	E3	30.3	48.0	3.60	24.30
	E5	27.5	49.0	3.90	22.80
	Mean	28.9	48.5	3.75	23.55
MCU 5	E3	26.8	49.0	4.20	22.60
	E5	22.8	51.0	5.20	19.90
	Mean	24.8	50.0	4.70	21.25
DS 28	E3	30.3	47.0	3.90	23.50
	E5	29.1	48.0	4.50	22.40
	Mean	29.7	47.5	4.20	22.95
ARBH 813	E3	28.5	48.0	4.30	22.40
	E5	28.3	47.0	4.70	21.80
	Mean	28.4	47.5	4.50	22.10
CD @ 5%	E3	0.08	2.01	0.432	2.14
	E5	2.06	2.93	0.366	1.34
	Mean	3.87	3.50	0.921	3.26
CV	E3	0.14	2.14	5.60	4.97
	E5	3.80	3.10	4.66	3.15

E3 – ARS, Dharwad (2013) and E5 – ARS, Bagalkot (2013)

It is also measure of lint yielding ability of a genotype which is used as raw material for textile industry. In present study, the variation recorded for lint index was from 3.64g to 6.95g. Three germplasm lines recorded 20 percent higher lint index than superior check, Sahana (5.32g). The genotypes like CPD-476, CPD-423, CPD-420, CPD-921, Abadhita and ARB-760 recorded high lint index (>6.0g) with high ginning outturn (>39.0 percent) and seed index (>9.3g), whereas the germplasm lines EC560395, EC137592, ACP-71, JBWR-23, IC356874 and L-761 exhibited high seed index (10.0g), with high lint index (>5.5g) and low ginning outturn (<35 percent). The genotypes like FQT-21, CAK-023A, CSHH-198F-Sirsa, 543395A03N98, F-2226, 543370A02N62 have recorded high seed index (>9.5g), low lint index (<4.5g) and low ginning outturn (<33 percent). Whereas, GTHV-08-70 (3.64g) recorded low and statistically on par with inferior check, MCU 5 (4.39g) over five environments. The variation observed for this trait was 2.21g to 10.02g, 2.15g to 7.59g, 3.40g to 7.42g, 2.97g to 7.26g and 3.06g to 6.74g with the mean values of 6.05g, 4.39g, 5.37g, 4.84g and 5.02g in E1, E2, E3, E4 and E5 respectively. Krishnados and Kadambavanasundaram (1997) observed 4.3g lint index. Nagaraj *et al.*, (2008) recorded 5.12 g lint index in elite germplasm lines. Bourland and Jones (2010) registered genotypes with 7.5 g lint index.

Out of 320 germplasm lines studied, the three germplasm viz., EC296596 (2263 Kg/ha), 128333-Acala-44 (2258 Kg/ha) and 543416A03N132 (2250 Kg/ha) recorded significantly higher yield than high yielding check and six other genotypes although statistically on par but recorded more than 10 percent seed cotton yield than superior check, ARBH 813 (1894 Kg/ha). Therefore nine germplasm lines can be potentially used to identify directly as varieties for commercial

cultivation. They possessed desirable level of ginning outturn (35.26 to 38.74%), longer fiber length (27.9 to 31.7 mm except one genotype with 25.4 mm) and desirable fiber strength (20.4 to 23.0 g/tex). 25 germplasm lines were significantly inferior and four germplasm lines recorded 40 percent lower seed cotton yield than inferior check, MCU 5 (1406 Kg/ha) and among genotypes IC357200 observe lowest yield 770 Kg per. In cotton, important yield contributing traits are number of bolls, boll weight and number of sympodia per plant. The development of superior lines for seed cotton yield depends on seed cotton yield per plant itself or number of bolls, boll weight and number of sympodia per plant. The range of variation was 412 to 3460 Kg per hectare, 255 to 1414 Kg per hectare, 675 to 3874 Kg per hectare, 539 to 2414 Kg per hectare and 614 to 3314 Kg per hectare with mean values 1804, 556, 2250, 1312 and 1532 Kg per hectare in E1, E2, E3, E4 and E5 environments respectively. Dhamayanthi *et al.*, (2008) observed seed cotton yield of 2301 kg/ha while handling the *G. hirsutum* x *G. barbadense* genotypes. Baig *et al.*, (2009) reported 1121kg/ha in *G. arboreum* genotypes. Patel *et al.*, (2009) recorded maximum of 96.51 g plant yield in Asiatic cotton lines. Bourland and Jones (2009) observed lint yield of 1265 and 1198 kg/ha from Arkot 9623 and Arkot 9625, respectively.

The variability of the fiber properties in cotton is an unfavourable element in a market that pits this natural fiber against artificial, more uniform products represented by synthetic fibers. Fiber properties vary as a function of the cultivar but also as a function of the environment and production practices (Clouvel *et al.*, 1998). The mean sum of squares for fiber quality traits in 320 *G. hirsutum* cotton germplasm evaluated in two environments are presented in Table 4. The

analysis of variance indicated presence of significant variability among the germplasm lines for all four fiber quality traits. The data on mean and range for yield and fiber traits are presented in Table 5 including checks.

Longer fiber is important in the textile industry because it produces stronger yarn leading to higher-priced end products. Recorded 2.5% span length was longest in CPD-476 (33.2 mm) which was on par with the superior check, DS 28 (29.7 mm) followed by five germplasm lines viz., FQT-21 (31.8 mm), IC356874 (30.9 mm), ADB-39 (30.9 mm), CPD-437 (30.0 mm) and EC559012 (30.0 mm) with good fiber strength (23.2 to 24.7 g/tex) and on par with ARBH 813 for seed cotton yield (1555 to 1966 Kg/ha). Whereas, EC138566 (23.2 mm) recorded lower 2.5% span length than MCU 5 (24.8 mm) with the mean of 28.0 mm over two environments. In E3 and E5 environments, 2.5% span length was highest in IC357200 (36.3 mm) and CPD-445 (33.4 mm) whereas, it was lowest in IC359059 (22.5 mm) and GTHV-08-70 (22.8 mm) with mean of germplasm 28.5 mm and 27.5 mm respectively. Varalaxmi has fibre length of 32.7mm in upland cotton developed by Katarki (1971). Katageri *et al.*, (2003) recorded 30.0 mm fibre length in recombinant lines. Nagaraj *et al.*, (2008) observed 27.12 mm fibre length in 20 elite germplasm lines.

Fiber strength is defined as the force necessary to break the fibers and depends on diameter of the cotton fibers. The average acceptable value of cotton fiber strength is 20 to 24 g/tex. It directly affects yarn strength. Strong yarn is processed efficiently and easily resulting in high yarn yield. Five genotypes like, FQT-21 (24.7 g/tex), ADB-39 (24.5 g/tex), IC359088 (23.7 g/tex), CPD-824 (23.7 g/tex) and IC356874 (23.6 g/tex) recorded high fiber strength with long fiber length (27.4 to 31.8 mm) and they are also

statistically on par with superior check, ARBH 813 for seed cotton yield (1555 to 1866 Kg/ha). Whereas, it was weakest in EC138566 (18.45 g/tex) and on par with inferior check, MCU 5 (21.25 g/tex) over two environments. Mean of germplasm lines for fibre strength was 21.94 g/tex and 21.68 g/tex in E3 and E5 environments respectively. Katarki (1971) developed an interspecific hybrid Varalaxmi with 24.8 g/tex fibre strength. Kulkarni and Khadi (1998) developed DLSa-17 variety of *G. arboreum* having fibre strength of 19-21 g/tex. Twenty three recombinant lines were obtained by Katageri *et al.*, (2003) which recorded fibre strength of 22 g/tex.

Highest uniformity ratio was recorded by CPD-921 (53.0%, 52.0% and 52.5%) than superior check, MCU 5 (49.0%, 51% and 50.0%) in E3, E5 and over two environments respectively followed by 100 germplasm lines recorded more than 48 percent uniformity ratio, which is considered to be excellent and statistically on par with superior check, MCU 5 (50.0%). However, it was lowest in IC357200 (44.0%) followed by three lines recorded less than 45 percent uniformity ratio over the check, Sahana (47.0%) over two environments that is below average grade for uniformity ratio. 48.26 % uniformity ratio was noticed in 20 elite germplasm lines by Nagaraj *et al.*, (2008).

Micronaire is the measure of fiber fineness. Thinner fibers are more durable, brighter and softer. Fine fiber forms stronger yarn and directly affects processing stages. In the present study, five germplasm lines have recorded more than 4.7 µg/in and fifteen lines have recorded fine micronaire value lower than Sahana (3.4 µg/in). Among them the line EC170338 (4.9 µg/in) was statistically on par with MCU 5 (4.7 µg/in), whereas it was finest in 543370A02N62 (2.9 µg/in) and on par with check, Sahana (3.4 µg/in) over two

environments. Mean of germplasm lines for micronaire value was 3.92 µg/in (E3) and 3.99 µg/in (E5). Krishnaswami and Kothandraman (1975) observed lines with 4.0 µg per inch micronaire. Nagaraj *et al.*, (2008) noticed 3.74 µg per inch micronaire value in study of 20 elite germplasm lines.

In conclusion the germplasm collections represent a valuable resource with more yield potential along with superior quality which were used for improving cotton varieties with high fibre yield and fiber quality and which are desirable source for the cotton breeding programme in wishes to transfer the desirable traits from the germplasm source to otherwise adapted agricultural cultivars.

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How to cite this article:

Suresh S. Handi and Katageri, I.S. 2018. Multi-Environment Evaluation to Identify Promising Germplasm Lines for Economically Important Traits in *G. hirsutum* Cotton. *Int.J.Curr.Microbiol.App.Sci.* 7(11): 929-944. doi: <https://doi.org/10.20546/ijcmas.2018.711.109>