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RESEARCH PAPER

Comprehensive evaluation of promising *Gossypium hirsutum* L. genotypes under rainfed conditions and their path of productivity analysis

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Abstract: The present study involves evaluation of 38 genotypes of *G. hirsutum* for productivity and fibre properties during *kharif* seasons of 2014-15 and 2015-16, at Agricultural Research Station, Dharwad Farm. The analysis of variance and pooled analysis revealed significant differences among the genotypes for all the traits studied across two years. Over two years of testing, the genotypes G h AM-46, MAP-20-4 and G h AM-9 were found to be high yielding and also had other desirable characters. Genotype G h AM-46 had high seed cotton yield and lint yield. G h AM-9 had desirable character of high boll weight while, MAP-20-4 had higher boll number. G h AM-9 can be considered an excellent genotype as it had relatively high yields coupled with good fibre length and fibre strength. The path of productivity analysis indicated existence of genetic diversity among potential genotypes and desirable deviations with respect to traits contributing to high productivity.

Key words: Cotton, Fibre quality, Genotype, Seed cotton yield

Introduction

Cotton is one of the most ancient and very important commercial fibre crops of global importance with a significant role in Indian agriculture, industrial development, employment generation and improving the national economy by earning valuable foreign exchange. Sustainable cotton production in the future will depend on the development of cotton varieties with higher yield potential and fibre quality as well as better tolerance to biotic and abiotic stresses. India has the largest area under cotton (10.50 m. ha) and also be the leading producer (35.10 m. bales). It is occupying much lower ranking in productivity (560 kg/ha) and is lower than the world average of 788 kg/ha (Anon., 2017).

Currently, there is an enormous need to further exploit the available genetic resources for greater benefits. Due to increase in the human population, the demand for textile materials has also been steadily increasing. Thus sincere efforts for genetic improvement of cotton varieties are required to increase productivity. This can be achieved through continuous selection for high yielding varieties with good fibre properties. An additional requirement is that they should also be well adapted to moisture stress conditions as much of the cotton area is under rainfed cultivation. The present study was aimed at exploring the yield and fibre quality potential of genotypes under rainfed conditions. The evaluation spread over two years also gave a better understanding of the interaction with environment. Apart from evaluating the genotypes for their productivity they can also be assessed for the different paths they take towards productivity via their traits. The genetic makeup of each individual being different is at the basis of such an assessment. Thus selection can be practiced for those traits contributing significantly to yield. It also helps in the selection of genetically diverse genotypes for crossing programs and is simpler than the path analysis method.

Material and methods

The experimental material comprised of 32 newly developed *G. hirsutum* L. genotypes along with six check varieties for comparison. This set of varieties was evaluated in a randomized complete block design with two replications, over two years, 2014-15 and 2015-16. Each entry was sown to three rows of 4.6 mt. Five plants in each entry were selected randomly, tagged and used for recording observations. The data obtained from two environments were subjected to environment wise analysis of variance followed by pooled analysis of data after confirmation of homogeneity by Hartley's F-maximum test (Rangaswamy, 2010). Fibre quality characters were analyzed under high volume instrument (HVI) at the CIRCOT regional quality evaluation unit situated at ARS, Dharwad farm. Statistical calculations were done using Windostat version 9.2.

Results and discussion

The thirty two *G. hirsutum* genotypes were compared with six check varieties for their productivity over two successive years *viz.,* 2014-15 and 2015-16. Some of the genotypes were superior over the checks for many of the yield and fibre traits. The analysis of variance pertaining to the set of 38 *G. hirsutum* genotypes for the two years is presented in Tables 1 and 2. Significant treatment mean sum of squares for all the 14 characters studied indicated eloquent variation among the genotypes. The material selected for the present investigation was quite appropriate for further genetic analysis as considerable amount of variability existed in both the years studied.

The pooled analysis of variance was carried out for the eight characters which showed homogeneity of error variance confirmed by Hartley's F_{max} test and is presented in Table 3. Pooled analysis of variance was done for sympodial length at 50 per cent plant height, boll number, ginning outturn, seed

Table 1. ANOVA for various quantitative characters in *G. hirsutum* cotton genotypes evaluated at during *kharif* 2014-15

Source of variation	df	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}
Replication	1	58.71	0.01	12.24	2.65	0.08	0.54	1.14	0.03	0.01	0.004	0.003	0.19	381.38	4.70
Treatment	37	279.83**	0.39**	9.91**	28.79**	1.29**	2.24**	10.34**	0.83**	10.64**	1.15**	0.63**	119.35**	2965.45**	159.55**
Error	37	50.85	0.003	3.58	2.03	0.41	0.61	0.31	0.29	0.09	0.003	0.004	9.64	158.56	4.53

Table 2: ANOVA for various quantitative characters in *G. hirsutum* cotton genotypes evaluated at during *kharif* 2015-16

Source of variation	df	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}
Replication	1	15.57	0.01	1.59	0.61	0.001	0.55	1.19	0.01	0.40	0.0003	0.02	36.96	126.37	7.02
Treatment	37	100.89**	0.07**	6.29**	20.28**	0.16**	0.39**	5.09**	0.48**	10.17**	1.06**	0.62**	135.28**	2071.61**	63.40**
Error	37	4.98	0.01	0.58	3.60	0.03	0.16	0.29	0.08	0.11	0.002	0.01	13.96	96.07	2.04

Note

X_1= Plant height (cm)
X_2= Number of monopodia per plant
X_3= Number of sympodia per plant
X_4= Sympodial length at 50 per cent plant height (cm)
X_5= Internodal distance (cm)
X_6= Interboll distance (cm)
X_7= Number of bolls per plant
X_8= Boll weight (g)
X_9= Ginning outturn (%)
X_{10}= Seed index (g)
X_{11}= Lint index (g)
X_{12}= Root dry weight (g)
X_{13}= Shoot dry weight (g)
X_{14}= Seed cotton yield per plant (g)
**= Significance at 1 % level
*= Significance at 5 % level

index, lint index, root dry weight, shoot dry weight and seed cotton yield per plant. It indicated significant difference between the two environments except for ginning outturn and environment x variety interaction for all traits. Significant differences were also noticed among the genotypes for all the traits studied. Results are in conformity to the studies of Laghari *et al.* (2003) and Nasir *et al.* (2007).

The genotypes G h AM-46 (9.00), G h AM-38 (8.50) and G h AM-32 (8.25) had higher boll number than the best check ARBH-813 (7.80) in 2014-15. While in 2015-16, the genotypes MAP-20-4 (12.30), G h AM-230 (11.25), G h AM-78 (8.60), MAP-33-34 (8.50) and 543361A02N32 (8.40) had better boll number than the best check MCU-5 (8.10). The pooled mean was 5.96 with a range of 9.53 (MAP-20-4) to 2.85 (HBS-146). There were no common genotypes over the two years proving the influence of environment.

During 2014-15, the best check Surabhi possessed a boll weight of 4.65 g and the genotypes G h AM-9 (4.90 g), EC560413 (4.75 g) and G h AM-78 (4.70 g) had higher boll weight than this check. While in 2015-16, the genotype RDT-17 had higher boll weight (5.75 g) than the best check MCU-5 (4.58 g). The other genotypes which had superior performance than MCU-5 were EC560413 (5.43 g), G h AM-9 (5.25 g), DS-28 (5.18 g) and EC560406 (5.08). Two of these genotypes *viz.,* EC560413 and G h AM-9 consistently had higher boll weight over the years. The boll weight in these two genotypes seems to be not much affected by environment, the reason for their stable expression.

During 2014-15, genotypes G h AM-46 (31.40 g) and EC560413 (27.40 g) had higher seed cotton yield per plant than the best check ARBH-813 (27.20 g). While in 2015-16, the genotype MAP-20-4 had higher seed cotton yield (40.00 g) than the best check, MCU-5 (33.50 g). The other genotypes which had superior seed cotton yield per plant than this check were G h AM-9 (35.50 g), G h AM-230 (34.50 g), MAP-13-51 (34.10 g) and G h AM-78 (33.85 g). The means for this trait were 14.35 g and 27.61 g in 2014-15 and 2015-16, respectively. Over two years, considerably high variability was found for seed cotton yield per plant. There existed significant difference between the environments. The pooled mean was 20.98 g with a range of 9.43 g (HBS-176) to 32.75 g (MAP-20-4). The top five genotypes along with best check in 2014-15 and 2015-16 for seed cotton yield and other important traits are presented in Tables 4 and 5, respectively. Stability analysis over 2 years across 6 locations indicated that the 9 genotypes that were tested responded differentially to the variable environments (Riaz *et al.*, 2013).

Regarding the fibre quality traits, the top five genotypes in both years were superior to the checks in fibre length. In 2014-15, HBS-146 had the highest fibre length (30.86 mm) followed by G h AM-9 (30.27 mm), while the lowest fibre length was reported by 543361A02N32 (24.88 mm). Whereas in 2015-16, genotype HBS-176 recorded highest fibre length (30.30 mm) followed by G h AM-9 (29.70 mm) and the lowest fibre length was recorded in Abadhita (23.30 mm). Over two years HBS-146 had higher fibre length (30.08 mm) followed by G h

Table 3. Pooled analysis of variance for eight characters in the *G. hirsutum* genotypes evaluated over two years

Source of variation	df	Sympodial length at 50 per cent plant height (cm)	Number of bolls per plant	GOT (%)	Seed index (g)	Lint index (g)	Root dry weight (g)	Shoot dry weight (g)	Seed cotton yield (g/plant)
Environment	1	2325.98**	201.02**	0.01	11.55**	3.35**	2889.72**	11028.80**	6676.67**
Variety	37	36.46**	11.09**	20.24**	2.19**	1.22**	198.39**	4218.66**	160.39**
Env. X Var.	37	12.61**	4.30**	0.57**	0.02**	0.03**	56.24**	818.40**	62.55**
Pooled Error	74	2.82	0.30	0.10	0.003	0.01	11.80	127.32	3.28

Table 4. Top five cotton genotypes in comparison with the best check for important traits during 2014-15

Genotype	Seed cotton yield (g/plant)	Genotype	Boll weight (g)	Genotype	Number of bolls per plant	Genotype	Fibre length (mm)	Genotype	Fibre strength (g/tex)
G h AM-46	31.40	G h AM-9	4.90	G h AM-46	9.00	HBS-146	30.86	HBS-176	30.85
EC560413	27.40	EC560413	4.75	G h AM-38	8.50	G h AM-9	30.27	G h AM-9	29.50
G h AM-38	26.00	G h AM-78	4.70	G h AM-32	8.25	EC560413	29.97	Surabhi	28.88
G h AM-32	25.75	MAP-20-45	4.60	G h AM-226	7.60	G h AM-159	29.88	MAP-13-51	28.77
MAP-20-4	25.50	HBS-157	4.55	MAP-13-51	7.20	G h AM-78	29.48	HBS-146	28.67
Best check									
ARBH-813	27.20	Surabhi	4.65	ARBH-813	7.80	ARBH-813	28.21	Abadhita	29.08

Table 5. Top five cotton genotypes in comparison with the best check for important traits during 2015-16

Genotype	Seed cotton yield (g/plant)	Genotype	Boll weight (g)	Genotype	Number of bolls per plant	Genotype	Fibre length (mm)	Genotype	Fibre strength (g/tex)
MAP-20-4	40.00	RDT-17	5.75	MAP-20-4	12.30	HBS-176	30.30	G h AM-254	26.20
G h AM-9	35.50	EC560413	5.43	G h AM-230	11.25	G h AM-9	29.70	HBS-176	24.20
G h AM-230	34.50	G h AM-9	5.25	G h AM-78	8.60	RDT-17	29.60	G h AM-46	23.70
MAP-13-51	34.10	DS-28	5.18	MAP-33-34	8.50	EC560406	29.50	HBS-1	23.70
G h AM-78	33.85	EC560406	5.08	543361A02N32	8.40	HBS-146	29.30	G h AM-258	23.60
Best check									
MCU-5	33.50	MCU-5	4.58	MCU-5	8.10	Sahana	26.90	Sahana	23.10

Table 6. Top five cotton genotypes in comparison with best check across two years for important traits

Genotype	Seed cotton	Number of yield (kg/ha)	Boll bolls per plant	Fibre weight (g)	Fibre length (mm)
strength (g/tex)					
G h AM-46	1577.41	8.45	4.18	26.27	25.82
MAP-20-4	1435.22	9.53	4.20	25.87	25.38
G h AM-9	1433.73	6.28	5.08	29.98	26.05
EC560413	1328.69	6.25	5.09	29.14	24.24
G h AM-78	1315.00	7.15	4.48	28.69	24.30
Best check					
ARBH-813	1180.78	7.08	4.33	27.16	25.47

AM-9 (29.98 mm) compared to the best check Sahana (27.26 mm). G h AM-9 was consistent in having longer fibre over years.

The trait fibre strength was highest in the genotype HBS-176 (30.85 g/tex) followed by G h AM-9 (29.50 g/tex), while MAP-20-45 recorded the lowest fibre strength (25.24 g/tex) in 2014-15. Whereas in 2015-16, G h AM-254 showed the highest fibre strength (26.20 g/tex) followed by HBS-176 (24.20 g/tex) while G h AM-159 recorded the lowest fibre strength (20.60 g/tex). Over two years HBS-176 had higher fibre strength (27.53 g/tex) followed by G h AM-254 (26.50 g/tex) compared to best check Abadhita (25.89 g/tex).

The micronaire value was the highest in G h AM-230 (4.50 ìg/inch) followed by G h AM-191 (4.40 ìg/inch), while the lowest was recorded in G h AM-9 (2.80 ìg/inch) in 2014-15. Whereas in 2015-16, genotype G h AM-226 recorded the highest micronaire value (5.60 ìg/inch) followed by G h AM-191 (5.20 ìg/inch) and the lowest was seen in G h AM-254 (3.90 ìg/inch). Over two years the best check ARBH-813 had micronaire value of 4.40 ìg/inch, while the genotypes which had superior performance than this check were G h AM-191 (4.80 ìg/inch) and G h AM-230 (4.80 ìg/inch). All genotypes showed desirable micronaire values over years.

During 2014-15, the genotype G h AM-46 had superior performance with high seed cotton yield and lint yield in comparison with best check ARBH-813, followed by EC560413. The other genotypes having higher yields were G h AM-38, G h AM-32 and MAP-20-4. In 2015-16, MAP-20-4 had superior performance with high seed cotton yield and lint yield in comparison with best check MCU-5, followed by G h AM-9, G h AM- 230, MAP-13-51 and G h AM-78. Across the two years, genotypes G h AM-46, MAP-20-4, G h AM-9 and G h AM-78 did exceedingly well. These genotypes figured in the top eight genotypes in the individual years of 2014-15 and 2015-16. Genotypes MAP-20-4 and G h AM-46 had high boll number while G h AM-9 and EC560413 had high boll weight. Genotypes G h AM-9, EC560413 and G h AM-78 had high fibre length whereas HBS-176 and G h AM-46 had high fibre strength. Genotypes G h AM-191, G h AM-230, EC560413 and MAP-20-4 had higher fibre fineness. The top five genotypes along with best check across two years for seed cotton yield and other important traits are presented in Table 6.

Across two years, the genotypes G h AM-46, MAP-20-4 and G h AM-9 were considered as excellent genotypes as they had superior performance with respect to seed cotton yield and also had good fibre quality traits. These genotypes can be released as new varieties after conforming to the requirements of general cultivation.

The second part of the analysis was about determining the path-to-productivity that the top performing genotypes took. The cause of superiority of potential genotypes was arrived at by comparing their performances with the mean of all genotypes and expressed as deviation from this overall mean. These per cent deviation values help in identifying the important yield contributing traits responsible for productivity seen in the group as well as in the superior genotypes. This per cent deviation for individual traits of potential genotypes from the group mean helps in identifying any differential gene contribution by the genotypes towards yield. The different paths that these genotypes take to become productive enable them to be chosen for hybridisation to further congregate the superior genes in to a hybrid or a segregant thereafter.

In the present study, top five potential genotypes of the year 2015-16 (MAP-20-4, G h AM-9, G h AM-230, MAP-13-51 and G h AM-78) were taken to calculate their per cent deviation from the group mean. With the help of this, it was possible to identify the role of different traits contributing to the superiority of these genotypes. The genotypic mean and per cent mean deviation of the top five genotypes from the overall mean is shown in Table 7.

The top performing genotypes as a group had positive deviation from the overall mean for number of bolls per plant (32.69 %), seed cotton yield per plant (28.91 %), plant height (8.25 %), number of monopodia per plant (6.83 %), number of sympodia per plant (6.40 %), ginning outturn (2.86 %), lint index (2.34 %) and fibre length (0.37 %). Positive deviation for these characters is the reason for their higher productivity. These results are in agreement with those of Mahantesh Shastri (2004),

Table 7. Genotypic mean of top five genotypes and their per cent deviations for different characters evaluated during *kharif* 2015-16

Genotype	Plant height (cm)	Number of monopodia	Number of sympodia	Number of bolls per plant	Boll weight (g)	GOT (%)	Seed index (g)	index xindex (g)	Excised leaf water loss (%)	Fibre length (mm)	Micronaire value (Ig/inch)	Fibre strength (g/tex)	Seed cotton yield (g/plant)
MAP-20-4	75.20	0.90	20.00	12.30	4.15	38.00	9.40	5.76	31.59	24.80	4.90	22.50	40.00
G h AM-9	78.50	0.80	20.50	6.75	5.25	37.50	9.92	5.95	27.75	29.70	4.40	22.60	35.50
G h AM-230	69.10	0.60	21.25	11.25	3.65	36.00	9.61	5.41	30.71	25.50	5.10	21.80	34.50
MAP-13-51	72.30	0.70	18.40	8.25	4.18	33.50	9.18	4.62	32.76	26.80	4.30	22.60	34.10
G h AM-78	75.40	0.50	21.50	8.60	4.25	36.25	9.80	5.57	30.67	27.90	4.20	21.60	33.85
Mean (Top5)	74.10	0.70	20.33	9.43	4.30	36.25	9.58	5.46	30.69	26.94	4.58	22.22	35.59
Overall mean	68.45	0.66	19.11	7.11	4.34	35.24	9.79	5.34	31.85	26.84	4.61	22.77	27.61
	Per cent deviations from group mean												
MAP-20-4	9.86	37.40	4.67	73.07	-4.44	7.82	-4.02	7.93	-0.82	-2.04	6.29	-1.19	44.88
G h AM-9	14.68	22.14	7.28	-5.02	20.88	6.40	1.29	11.50	-12.86	2.86	-4.56	-0.75	28.58
G h AM-230	0.95	-8.40	11.21	58.29	-15.96	2.15	-1.88	1.27	-3.58	-1.34	10.63	-4.26	24.96
MAP-13-51	5.62	6.87	-3.71	16.08	-3.87	-4.95	-6.32	-13.40	2.86	-0.04	-6.72	-0.75	23.51
G h AM-78	10.15	-23.66	12.52	21.01	-2.14	2.86	0.06	4.40	-3.69	1.06	-8.89	-5.14	22.60
% Mean deviation (Top 5)		8.25	6.83	6.40	32.69	-1.11	2.86	-2.17	2.34	-3.62	0.37	-0.65	-2.42 28.91

Lavanyakumar (2004), Gururaj (2006), Ranganatha and Patil (2015) and Kencharaddi (2015) with regards to the above said traits, albeit with magnitude variations in the per cent deviations, where all these authors reported positive deviations.

Negative deviation was observed for excised leaf water loss (-3.62 %) which is desirable since genotypes having lesser excised leaf water loss will have higher water retention capacity, thus contributing to moisture stress tolerance. However, there was minor negative deviation for fibre strength (-2.42 %), seed index (-2.17 %), boll weight (-1.11 %) and micronaire value (-0.65 %). Rajeev (2011) observed similar negative deviations for the above characters.

Two conclusions emerge from this study. Firstly, based on the path of productivity, any two genotypes differing in their paths to productivity can be hybridized to bring together the different genes responsible for higher yield present in them. Superior segregants can also be isolated later from such a cross. Here, genotypes G h AM-9 and MAP-13-51 had contrasting paths to their productivity with respect to the characters number of sympodia per plant, boll number, boll weight, ginning outturn, seed index, lint index, excised leaf water loss and fibre length. These genotypes can be used for hybridization to embark upon a fresh breeding program. Secondly, considering the overall performance across two years, the three genotypes G h AM-46, MAP-20-4 and G h AM-9 proved to be promising as they had superior seed cotton yield with good fibre quality traits. These genotypes can be released as new varieties following extensive testing at the national level.

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