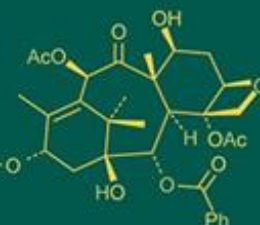
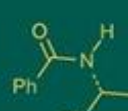
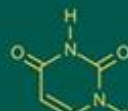
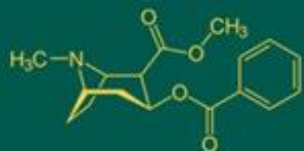


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Multi-Environment assessment of stability for seed cotton yield and its component traits in cotton (*Gossypium hirsutum* L.)

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Abstract

Developing cotton genotypes with broad adaptability remains an important objective in plant breeding and multi-environment testing plays a vital role in identifying stable and highyielding genotypes. In the present study, 21 hybrids developed through a line $\times$ tester mating design involving seven lines and three testers, along with 10 parents, evaluated across three environments: Sardarkrushinagar (E₁), Khedbrahma (E₂) and Talod (E₃). Stability analysis for 19 traits was carried out using the Eberhart and Russell (1966) [1] model. Significant differences among genotypes and environments indicated variable performance of genotypes under different environmental conditions. Significant genotype $\times$ environment interaction was observed for several important traits, including plant height, number of monopodia per plant, number of sympodia per plant, leaf area, boll weight, seed cotton yield per plant, ginning outturn, lint index, upper half mean length and uniformity ratio. Talod (E₃) was identified as the most favourable environment for seed cotton yield per plant and associated traits based on environmental indices. None of the parents or hybrids showed average stability for all traits across environments. However, stability parameters such as mean performance, regression coefficient (bi) and deviation from regression (S²di) identified the hybrids GT-84 $\times$ G. Cot.10 BG-II, GTHV-13/28 $\times$ CICRBT-20031, MCB-16-1 $\times$ CICRBT-20031 and MCB-69 $\times$ CICRBT-20031 as stable and widely adapted for seed cotton yield and related traits. Among the parents, GT-84 and BC-68-2-3 were found to be stable for seed cotton yield per plant and may serve as valuable donors in cotton breeding programmes aimed at improving stability and adaptability.

Keywords: Cotton, seed cotton yield per plant, stability analysis, eberhart and russell model

Introduction

Cotton (*Gossypium* spp.) is one of the most important commercial fibre crops cultivated across tropical and subtropical regions of the world. Often referred to as the “White Gold” or the “King of Fibre”. Cotton occupies a significant place in the agricultural economy due to its wide industrial utility and contribution to employment generation, trade and rural livelihoods. Among different breeding strategies, hybrid development using genetically diverse parents has emerged as an effective method for enhancing yield potential and improving desirable agronomic traits. In cotton breeding programmes, the identification of stable and high-performing genotypes across varied environmental conditions is considered an important objective. However, yield and related traits in cotton are quantitative in nature and are greatly influenced by environmental fluctuations. As a result, the performance of a genotype often varies from one environment to another, giving rise to genotype $\times$ environment (G $\times$ E) interaction. The presence of G $\times$ E interaction creates difficulties in selecting superior genotypes because the relative performance and ranking of genotypes may not remain consistent under different environmental conditions. A genotype performing well in one location or season may not necessarily show similar performance elsewhere. Such inconsistencies complicate the process of selection and reduce the precision of evaluating the true genetic potential of breeding materials. Changes in genotype ranking across environments are among the major consequences of G $\times$ E interaction, making varietal evaluation more complex. [Cooper and DeLacy (1994) [2]] Although G $\times$ E interaction is often considered a limitation in crop improvement programmes, it can also provide useful information regarding the adaptability of genotypes to specific or diverse environments. [Kang (1998) [3]].

In plant breeding, stability refers to the ability of a genotype to maintain consistent performance over a wide range of environmental conditions. Phenotypic stability depends mainly upon the genetics of the genotype concerned and its capacity to tolerate to environment changes. Hence, breeders generally test breeding lines and hybrids in more than one environment prior to selecting genotypes for commercial production.

Testing of genotypes in more than one location and season enables us to know the adaptability pattern of genotypes so that stable and widely adapted lines can be identified. Seed cotton yield is a quantitative trait which is influenced by a large number of genes and also very sensitive to environmental conditions. Genotype $\times$ environment interaction could happen due to differences in either the amount of response or ranking of the genotypes under different conditions. The study of $G \times E$ interaction serves two purposes first, we can identify stable genotypes; secondly, the suitability of different genotypes for a particular environment will also become clear. It further assists breeders in selecting appropriate testing locations, improving selection efficiency and formulating effective breeding strategies. Baker (1969)^[4] also highlighted the importance of $G \times E$ interaction studies in estimating genetic parameters accurately and in designing reliable crop improvement programmes. Therefore, evaluation of genotypes under diverse environmental conditions remains a crucial step for developing stable, high yielding and adaptable cotton hybrids suitable for varied agro-climatic regions.

Materials and Methods

The experimental material for the present investigation comprised 21 F_1 hybrids developed through a line $\times$ tester mating design involving seven lines and three testers, along with their 10 parents and a standard check hybrid, G. Cot. Hy-26 BG-II. The crosses were generated during kharif-2023 at the Cotton Research Station, Sardarkrushinagar Dantiwada Agricultural University, Talod. These 32 genotypes including standard check were subsequently evaluated using Randomized Block Design with three replications under three different locations, namely Sardarkrushinagar (E_1), Khedbrahma (E_2)

and Talod (E_3) in kharif 2024-25. The parental lines were maintained through selfing to ensure genetic purity. Each genotype was grown in rows of 4.0 m length by maintaining a spacing of 120 cm between rows and 45 cm between plants. Recommended agronomic practices and necessary plant protection measures were followed uniformly throughout the crop growth period to raise a healthy and uniform crop stand. Observations on various quantitative and qualitative traits were recorded from randomly selected competitive plants, excluding border plants to minimize environmental bias. The selected plants were properly tagged and numbered for recording observations on different characters. The mean values obtained from these observations were used for statistical analysis. Stability analysis and assessment of genotype $\times$ environment interaction were carried out following the model proposed by Eberhart and Russell (1966)^[1] to identify stable and widely adapted genotypes for seed cotton yield and its associated traits across different environments.

Results and Discussion

The analysis of variance for stability revealed highly significant differences among genotypes for all the traits studied when tested against pooled error (Table 1), indicating the presence of considerable genetic variability among the genotypes. Mean squares due to environments were also significant for important traits such as plant height, number of monopodia per plant, number of sympodia per plant, leaf area, weight of seed cotton in second harvest, seed cotton yield per plant, boll weight, ginning outturn, lint index, upper half mean length and fibre strength, suggesting that environmental conditions markedly influenced the expression of these traits.

Table 1: Analysis of variance over the environment for stability for different characters in cotton

Source of variation	d.f.	DF	PH	NMPP	NSPP	LA	BNFH	WSCFH	BNSH	WCSH	NBPP
Genotype	31	57.18**	1246.25**	1.75**	54.04**	4637838.00**	19.66**	490.89**	43.07**	1541.36**	105.55**
Environment	2	8.17	612.81**	1.91**	18.22**	458495.11*	2.47	239.10**	0.42	218.75*	3.97
$G \times E$	62	5.34	452.60**	0.09*	5.75**	595861.46**	1.09	45.25	1.16	124.46**	2.04
Env. + ($G \times E$)	64	1.81	152.53**	0.11**	2.05**	197189.59**	0.38	7.42	0.38	87.16*	0.70
Env. (Linear)	1	5.45	408.54*	1.27**	12.15**	305663.4**	1.65	159.40**	0.28	145.84**	2.64
$G \times E$ (Linear)	31	1.84	279.99***++	0.087*++	5.69***++	235087.48**	0.32	5.71	0.41	106.58**	0.66
Pooled deviation	32	1.67	21.06	0.01	2.08**	157086.19**	0.39	4.32	0.35	55.39	0.68
Pooled error	186	4.50	72.10	0.06	0.73	87195.45	2.20	47.23	1.70	60.58	4.66

Source of variation	d.f.	SCYPP	BW	SI	GOT	LI	UHML	MIC	FS	UR
Genotype	31	3524.82**	1.87**	1.459**	15.22**	0.90**	7.48**	0.64**	9.56**	10.45**
Environment	2	878.73**	0.48**	0.017	14.01*	0.51*	2.57**	0.26	4.23*	5.218**
$G \times E$	62	227.94*	0.14**	0.004	6.22**	0.24**	0.93**	0.07	1.09	1.82**
Env. + ($G \times E$)	64	319.47**	0.10*	0.001	5.85*	0.08	0.74**	0.03	0.40	0.59
Env. (Linear)	1	585.82**	0.32*	0.012	8.47**	0.34**	1.72*	0.17	2.82	0.52
$G \times E$ (Linear)	31	110.05	0.17**	0.001	7.31***++	0.27***++	0.87***++	0.03	0.48+	1.07***++
Pooled deviation	32	287.89**	0.12*	0.001	1.67	0.07	0.17	0.02	0.24	0.14
Pooled error	186	158.39	0.07	0.013	3.73	0.15	0.39	0.11	0.97	0.986

*, ** Significant at 5 and 1 per cent level, respectively when tested against pooled error mean square for all the sources. +, ++ significant at 5 and 1 per cent level, respectively when tested against pooled deviation mean square for $G \times E$ (Linear). DF= Days to flowering, PH= Plant height, NMPP= Number of monopodia per plant, NSPP= Number of sympodia per plant, LA= Leaf area, BNFH= Boll number in first harvest, WSCFH= Weight of seed cotton in first harvest, BNSH= Boll number in second harvest, WCSH= Weight of seed cotton in second harvest, NBPP= Number of bolls per plant, SCYPP= Seed Cotton yield per plant, BW= Boll weight, SI= Seed index, GOT= Ginning outturn, LI= Lint Index, UHML= Upper half mean length, UR= Uniformity ratio, MIC= Micronaire and FS= Fibre strength.

The genotype $\times$ environment ($G \times E$) interaction was significant for traits likes, plant height, number of monopodia per plant, number of sympodia per plant, leaf area, weight of seed cotton in second harvest, seed cotton yield per plant, boll weight, ginning outturn, lint index, upper half mean length and

uniformity ratio when tested against pooled error (Table 1). This indicated differential response of genotypes under varying environmental conditions. However, remaining traits showed non-significant $G \times E$ interaction, indicating relatively stable performance across environments. Hence, stability analysis for

these traits was not carried out. The combined effect of environment and genotype $\times$ environment interaction [$E+(G \times E)$] was significant for plant height, number of monopodia per plant, number of sympodia per plant, leaf area, weight of seed cotton in second harvest, seed cotton yield per plant, boll weight, ginning outturn and upper half mean length, fulfilling the basic requirement for stability analysis. The total variation was further partitioned into environment (linear), $G \times E$ (linear) and pooled deviation components as suggested by Eberhart and Russell (1966) [1].

Only, $G \times E$ (linear) component was tested against pooled deviation, whereas the remaining components were tested against pooled error. This approach was adopted because pooled deviation serves as the appropriate error term for testing the predictability of genotypic response across environments under the Eberhart and Russell model. The linear component of $G \times E$ represents the predictable portion of interaction associated with regression response and therefore its significance is more appropriately judged against pooled deviation rather than pooled error. Both environment (linear) and $G \times E$ (linear) components were significant for several traits, indicating that much of the variation was governed by predictable environmental effects and differential linear response of genotypes. For seed cotton yield per plant, only environment (linear) was significant, suggesting a greater influence of

environmental factors on yield expression. The higher magnitude of environment (linear) over $G \times E$ (linear) for most traits further confirmed the dominant role of environmental effects.

The pooled deviation component was non-significant for most traits except number of sympodia per plant, leaf area, seed cotton yield per plant and boll weight, indicating that genotype performance for most characters was largely predictable across environments. Significant pooled deviation for a few traits suggested the involvement of both predictable and unpredictable components in the expression of these characters. Similar findings were also reported by Saini *et al.* (2008) [5], Satish *et al.* (2009) [6], Nidagundi *et al.* (2010) [7], Singh *et al.* (2014) [8], Patil *et al.* (2017) [9], Abro *et al.* (2021) [10], Murthy and Pradeep (2022) [11] and Suresh (2023) [12].

Overall, the present findings highlighted the significant influence of both genetic makeup and environmental conditions on the expression and stability of different traits, emphasizing the importance of multi-environment evaluation for identifying stable and widely adapted cotton genotypes suitable for effective breeding programmes and commercial cultivation.

Environmental indices for the nineteen traits are presented in Table 2. The indices revealed differential expression of traits across environments, indicating varied environmental influence on the performance of genotypes.

Table 2: Estimates of environmental index (I_j) for various characters under different locations in cotton

Sr. No.	Characters	Environmental Index (I _j)		
		Sardarkrushinagar	Khedbrahma	Talod
1	Days to flowering	-0.30	0.01	0.29
2	Plant height	-2.79	0.65	2.14
3	Number of monopodia per plant	-0.09	0.16	-0.07
4	Number of sympodia per plant	-0.48	0.36	0.12
5	Leaf area	-65.95	-5.94	71.89
6	Boll number in first harvest	0.10	-0.19	0.09
7	Weight of seed cotton in first harvest	-0.26	-1.43	1.69
8	Boll number in second harvest	0.08	-0.04	-0.04
9	Weight of seed cotton in second harvest	0.45	-1.68	1.24
10	Number of bolls per plant	0.18	-0.22	0.05
11	Seed cotton yield per plant	0.19	-3.11	2.93
12	Boll weight	0.04	-0.07	0.07
13	Seed index	0.00	-0.02	0.02
14	Ginning outturn	-0.34	-0.004	0.33
15	Lint index	-0.07	-0.008	0.08
16	Upper half mean length	-0.03	-0.15	0.18
17	Micronaire	-0.01	-0.04	0.06
18	Fibre strength	0.04	0.18	-0.22
19	Uniformity ratio	-0.05	-0.05	0.10

Among the three environments, Sardarkrushinagar (E_1) was favourable for traits such as days to flowering, plant height, number of monopodia per plant, boll number in first and second harvest and number of bolls per plant. Khedbrahma (E_2) provided favourable conditions for number of sympodia per plant, micronaire and fibre strength. In contrast, Talod (E_3) was favourable for a majority of the traits, including leaf area, seed cotton weight in both harvests, seed cotton yield per plant, boll weight, seed index, ginning outturn, lint index, upper half mean length and uniformity ratio (Table 2). Overall, Talod (E_3) emerged as the most suitable environment for seed cotton yield and most of its contributing traits, whereas Khedbrahma (E_2) was comparatively less favourable for yield and related characters. According to the stability model proposed by Eberhart and Russell (1966) [1], genotypes exhibiting high mean performance, regression coefficient close to unity ($bi = 1$) and non-significant deviation from regression ($S^2di = 0$) are

considered stable and widely adapted across environments. Genotypes possessing higher mean values with regression coefficients greater than unity ($bi > 1$) along with non-significant deviations from regression are considered more responsive to favourable environmental conditions. On the other hand, genotypes with higher mean performance coupled with regression coefficients less than unity ($bi < 1$) and non-significant deviations from regression are regarded as better suited to comparatively poor or unfavourable environments. In the present study, non-significant regression coefficients were considered as unity, while nonsignificant deviation from regression values were treated as zero or minimum deviation. Therefore, genotypes exhibiting high mean performance along with non-significant bi and S^2di values were identified as stable for the respective traits across environments. The results of the stability analysis for eleven characters are presented in table 3 to 7.

Table 3: Stability parameters for plant height, number of monopodia per plant and Number of sympodia per plant in cotton

Sr. No.	Genotypes	Plant height			Number of monopodia per plant			Number of sympodia per plant		
		μ_i (cm)	bi	S ² di	μ_i	bi	S ² di	μ_i	bi	S ² di
1.	BC-68-2-3	158.94	7.63++	0.97	2.96	0.70	-0.019	15.88	1.16	-0.24
2.	BC-68-2-4	127.76	-3.75++	-13.00	2.44	0.12++	-0.018	15.53	1.15	-0.23
3.	BC-68-1145-42	148.58	3.73++	-17.24	2.91	2.58++	-0.014	18.29	1.56	0.31
4.	MCB-16-1	141.85	-0.25	-12.91	3.07	1.64++	-0.020	17.21	-4.16	16.31 **
5.	MCB-69	161.37	5.40+	19.57	2.40	-1.21++	-0.016	16.00	1.32	-0.22
6.	GTHV-13/28	128.72	0.34+	-22.63	1.82	-1.00++	-0.003	13.48	2.97	1.81 **
7.	GT-84	142.01	10.09++	53.04	2.80	-0.03+	-0.011	14.41	-0.25	0.31
8.	4190 Bt	140.18	3.21++	-19.91	2.71	1.31	0.022	16.01	3.69++	0.14
9.	CICRBT-20031	154.86	6.64++	13.21	3.24	1.36++	-0.020	15.24	2.88	0.38
10.	G. Cot. 10 BG-II	122.11	-1.72++	-22.71	3.42	2.75++	-0.0163	17.06	3.08+	0.10
11.	BC-68-2-3 × 4190 Bt	150.99	0.03	-19.39	2.62	-0.18	-0.001	19.2	-1.70	1.37 *
12.	BC-68-2-3 × CICRBT-20031	139.88	-4.36++	-16.58	3.04	1.79++	-0.020	15.49	2.97	1.29 *
13.	BC-68-2-3 × G. Cot.10 BG-II	156.09	7.31++	-8.79	2.31	0.97	-0.019	21.71	1.38	1.39 *
14.	BC-68-2-4 × 4190 Bt	122.57	-0.80++	-21.25	3.93	1.64++	-0.020	21.29	-1.33	3.36 **
15.	BC-68-2-4 × CICRBT-20031	159.19	-1.26	-16.78	3.07	0.82++	-0.020	20.64	-1.54++	-0.09
16.	BC-68-2-4 × G. Cot.10 BG-II	145.79	-2.44+	-1.37	2.60	0.37	0.001	20.24	2.27	0.43
17.	BC-68-1145-42 × 4190 Bt	156.77	10.70++	96.26 *	2.51	-0.27++	-0.020	18.97	1.55	-0.11
18.	BC-68-1145-42 × CICRBT-20031	135.24	-5.33++	22.39	2.49	-0.12++	-0.018	18.49	1.33	0.43
19.	BC-68-1145-42 × G. Cot.10 BG-II	144.96	0.83	-23.66	3.16	1.46	0.005	21.08	-1.42	3.97 **
20.	MCB-16-1 × 4190 Bt	154.39	4.93++	-9.45	3.62	1.17	0.053	15.57	4.15	3.51 **
21.	MCB-16-1 × CICRBT-20031	129.97	-7.94++	30.48	3.64	2.60++	-0.020	19.2	2.10	0.19
22.	MCB-16-1 × G. Cot.10 BG-II	143.05	-2.32+	-0.78	3.18	3.84++	-0.018	19.13	4.41	4.00 **
23.	MCB-69 × 4190 Bt	160.39	5.15++	-19.53	2.67	0.00++	-0.020	18.93	4.2	3.38 **
24.	MCB-69 × CICRBT-20031	140.85	-6.07++	49.13	2.82	1.54	-0.005	18.72	-2.79	10.37 **
25.	MCB-69 × G. Cot.10 BG-II	152.26	0.06++	-22.85	2.33	0.42++	-0.018	18.79	0.62	0.47
26.	GTHV-13/28 × 4190 Bt	138.96	0.62	-19.79	3.09	1.51++	-0.019	20.49	0.71	0.22
27.	GTHV-13/28 × CICRBT-20031	160.91	1.12	-2.60	3.03	2.27	-0.018	20.33	0.41	0.30
28.	GTHV-13/28 × G. Cot.10 BG-II	128.79	-2.36++	-16.88	2.58	0.60	0.013	19.87	1.76	1.73 **
29.	GT-84 × 4190 Bt	160.03	-0.89	-18.53	2.97	1.21	-0.013	22.79	-1.02++	-0.24
30.	GT-84 × CICRBT-20031	147.67	-0.16++	-22.47	2.56	0.67	-0.017	20.18	-1.28	4.60 **
31.	GT-84 × G. Cot.10 BG-II	139.19	-2.60++	-7.49	2.78	1.42	0.010	22.86	0.14	-0.18
32.	G. Cot. Hy-26-BG-II	140.08	1.06	-23.61	3.22	0.27++	-0.020	19.09	1.70	-0.16
	Mean	72.27			144.83			72.27		

+ and ++ indicate significance of regression coefficient (*bi*) from unity at 5% and 1% levels, respectively. \ and \\\ indicate significance of deviation from regression (*S²di*) at 5% and 1% levels, respectively.

For plant height, six hybrids exhibited lower mean values along with regression coefficients close to unity and non-significant deviation from regression, indicating average stability and wide adaptability across environments. Among these, GTHV-13/28 × 4190 Bt, BC-68-1145-42 × G. Cot.10 BG-II, BC-68-2-3 × 4190 Bt and BC-68-2-4 × CICRBT-20031 were identified as stable hybrids for reduced plant height (Table 3). In case of number of monopodia per plant, eleven hybrids showed desirable mean performance coupled with nearly unit regression coefficients and non-significant deviation from regression, suggesting stable performance over environments. Among them, BC-68-2-3 & × G Cot.10 BG-II, GT-84 × CICRBT-20031, GTHV-13/28 × G. Cot.10 BG-II and BC-68-2-4 × G. Cot.10 BG-II were found superior and widely adapted (Table 3). For number of sympodia per plant, eight hybrids recorded higher mean values with regression coefficients close to unity and non-significant deviation from regression, indicating

average stability and wider adaptability. The promising hybrids under this category were GT-84 × G. Cot.10 BG-II, GTHV-13/28 × 4190 Bt, GTHV-13/28 × CICRBT-20031 and BC-68-2-4 × G Cot.10 BG-II (Table 3). Nine hybrids exhibited stable performance for leaf area with higher mean values, unit regression response and non-significant deviation from regression. Among these, GT-84 × 4190 Bt, MCB-16-1 × G. Cot.10 BG-II and BC-68-1145-42 × 4190 Bt were identified as widely adapted hybrids for this trait (Table 4). For weight of seed cotton in second harvest, most of the hybrids showed regression coefficients around unity with non-significant deviations from regression, suggesting stable behaviour across environments. Among them, GTHV-13/28 × CICRBT-20031, GT-84 × G. Cot.10 BG-II and MCB-16-1 × CICRBT-20031 recorded superior mean performance and average stability (Table 4).

Table 4: Stability parameters for leaf area and Weight of seed cotton in second harvest in cotton

Sr. No.	Genotypes	Leaf area			Weight of seed cotton in second harvest		
		$\mu_i(\text{cm}^2)$	bi	S2di	$\mu_i(\text{g})$	bi	S2di
1.	BC-68-2-3	10032.08	-0.35	107105.68 *	90.51	0.27++	-19.99
2.	BC-68-2-4	11399.71	-11.87	981967.34 **	94.87	-1.85++	20.10**
3.	BC-68-1145-42	10794.9	4.45++	-23684.34	70.74	-0.01	-16.19
4.	MCB-16-1	10960.86	4.80++	-21171.57	72.48	1.79	-16.86
5.	MCB-69	11134.71	5.09++	-18812.69	70.92	1.12++	-20.19
6.	GTHV-13/28	11314.59	5.27++	-17070.91	72.17	1.48	-16.61
7.	GT-84	11498.92	5.41++	-16100.21	84.64	1.45	-18.53
8.	4190 Bt	11684.39	5.52++	-14678.95	69.66	-0.49++	-19.14
9.	CICRBT-20031	11872.53	5.54++	-14059.05	85.20	-0.45++	-19.02
10.	G. Cot. 10 BG-II	12060.94	5.56++	-13230.68	78.26	1.03	-18.01
11.	BC-68-2-3 × 4190 Bt	9851.24	-2.40+	-9752.40	83.07	1.52	-9.19
12.	BC-68-2-3 × CICRBT-20031	10586.24	1.38	-16810.01	92.8	1.23	-12.00
13.	BC-68-2-3 × G. Cot.10 BG-II	11774.16	2.19+	-26910.30	78.91	1.58	-12.06
14.	BC-68-2-4 × 4190 Bt	10167.73	0.13++	-28562.92	86.86	-1.25	11.77**
15.	BC-68-2-4 × CICRBT-20031	10167.52	0.51	80879.91	88.74	0.01	-16.85
16.	BC-68-2-4 × G. Cot.10 BG-II	11122.03	-13.31	758715.13 **	98.57	0.67	-11.23
17.	BC-68-1145-42 × 4190 Bt	11264.76	-13.14	754877.49 **	71.97	1.65	-9.63
18.	BC-68-1145-42 × CICRBT-20031	10747.16	0.69	-28387.00	110.86	0.21	19.20**
19.	BC-68-1145-42 × G. Cot.10 BG-II	10893.24	0.96	-28409.39	100.49	3.03	-13.49
20.	MCB-16-1 × 4190 Bt	11041.51	1.23	-28099.27	87.68	1.96	-12.56
21.	MCB-16-1 × CICRBT-20031	11190.07	1.35	-28035.49	106.18	-0.53	3.77
22.	MCB-16-1 × G. Cot.10 BG-II	11335.70	1.61	-27217.97	82.13	1.16	-13.83
23.	MCB-69 × 4190 Bt	12339.71	2.50++	-26678.95	87.62	1.42	-18.01
24.	MCB-69 × CICRBT-20031	11627.52	2.01+	-26813.20	96.29	-0.13	-17.85
25.	MCB-69 × G. Cot.10 BG-II	10028.62	0.05	-28763.48	80.93	1.40	6.72
26.	GTHV-13/28 × 4190 Bt	11921.32	2.31+	-26599.49	91.61	2.68	-16.84
27.	GTHV-13/28 × CICRBT-20031	12067.06	2.42++	-26492.10	120.57	1.19	-19.51
28.	GTHV-13/28 × G. Cot.10 BG-II	12205.32	2.51++	-26532.72	80.01	1.53	-18.06
29.	GT-84 × 4190 Bt	11481.99	1.78	-27201.70	95.54	0.16++	-19.87
30.	GT-84 × CICRBT-20031	12463.40	2.46++	-27015.48	101.34	1.37+	20.08**
31.	GT-84 × G. Cot.10 BG-II	11067.27	-0.03	203120.03 **	114.17	3.20	-10.65
32.	G. Cot. Hy-26-BG-II	12245.12	5.40++	-11914.89	92.34	2.40++	-19.61
	Mean	144.83			88.69		

+ and ++ indicate significance of regression coefficient (bi) from unity at 5% and 1% levels, respectively. \ and \ indicate significance of deviation from regression (S^2di) at 5% and 1% levels, respectively.

Seed cotton yield per plant, being the most important economic trait in cotton, was assessed by simultaneous consideration of mean performance, regression coefficient and deviation from regression. Among the parents, GT-84 and BC-68-2-3 recorded higher mean seed cotton yield along with unit regression coefficient and non-significant deviation from regression, indicating stable performance and wide adaptability across environments (Table 5). Among the hybrids, fourteen crosses exhibited higher mean seed cotton yield than the

overall mean along with regression coefficients close to unity and non-significant deviation from regression, indicating average stability and wider adaptability. The top stable hybrids identified for seed cotton yield per plant were GT-84×G. Cot.10 BG-II, GTHV-13/28 × CICRBT-20031, MCB-16-1 × CICRBT-20031 and MCB-69 × CICRBT-20031 (Figure 1). These hybrids also performed consistently for several yield contributing traits, suggesting their suitability for cultivation under diverse environmental conditions.

Table 5: Stability parameters for Seed cotton yield per plant, Boll weight and Ginning outturn in cotton

Sr. No.	Genotypes	Seed cotton yield per plant			Boll weight			Ginning outturn		
		$\mu_i(\text{g})$	bi	S2di	$\mu_i(\text{g})$	bi	S2di	$\mu_i(\%)$	bi	S2di
1.	BC-68-2-3	138.68	1.53	-42.81	4.23	1.42++	-0.0230	29.78	-4.31	2.37
2.	BC-68-2-4	146.28	0.16	38.82*	4.59	0.48+	0.0223	31.60	1.30	-0.94
3.	BC-68-1145-42	109.59	0.02+	-48.63	3.30	0.95	-0.0230	29.95	1.31	6.87 *
4.	MCB-16-1	112.61	1.34	-50.19	3.76	1.18	-0.0227	33.60	-3.21+	-0.23
5.	MCB-69	111.40	1.01	-52.80	3.47	0.95	0.0230*	33.33	-1.67	-0.65
6.	GTHV-13/28	118.87	1.79	-45.47	3.34	1.19	-0.0229	32.71	0.79	-0.47
7.	GT-84	138.93	1.19	16.58	4.01	1.19	-0.0229	31.42	2.47	3.63 *
8.	4190 Bt	108.37	0.15	-45.93	3.47	1.42++	-0.0230	31.51	-1.97	0.12
9.	CICRBT-20031	134.00	0.98	-49.39	4.11	1.19	-0.0229*	33.45	-2.68	4.76 *
10.	G. Cot. 10 BG-II	125.86	0.85+	-52.70	3.8	1.42++	-0.0230	33.96	-3.25++	-1.16
11.	BC-68-2-3 × 4190 Bt	124.81	1.12	-32.94	3.57	0.50	0.0166*	31.88	-1.11	1.92
12.	BC-68-2-3 × CICRBT-20031	142.23	1.55	-34.86	4.03	0.22	-0.0213	33.88	1.69	-1.14
13.	BC-68-2-3 × G. Cot.10 BG-II	123.94	1.88++	52.71**	3.48	1.19	-0.0229	34.69	1.90	-0.67
14.	BC-68-2-4 × 4190 Bt	132.81	0.58	-17.85	3.54	0.71+	-0.0229	30.30	-0.48	0.64

15.	BC-68-2-4 × CICRBT-20031	137.60	0.65	-51.35	3.73	0.95	-0.0230	32.99	1.34	-1.20
16.	BC-68-2-4 × G. Cot.10 BG-II	146.78	0.84	31.16*	4.27	1.12	0.0201*	32.35	0.74	-1.12
17.	BC-68-1145-42 × 4190 Bt	111.89	1.31	16.63	3.08	0.71+	-0.0229	31.70	1.18	-1.19
18.	BC-68-1145-42 × CICRBT-20031	166.38	-0.16+	-47.15	4.51	0.96	-0.0203	32.17	7.40	1.76
19.	BC-68-1145-42 × G. Cot.10 BG-II	154.72	2.33+	46.70**	4.16	1.18	0.0227	31.42	3.63++	-1.17
20.	MCB-16-1 × 4190 Bt	139.10	0.82	-52.43	3.86	1.18	-0.0227	33.14	0.64++	-1.24
21.	MCB-16-1 × CICRBT-20031	163.50	0.28	26.08	4.51	0.71+	-0.0229	32.05	5.50	1.33
22.	MCB-16-1 × G. Cot.10 BG-II	129.63	1.35	-49.39	3.54	1.19	0.0229*	33.71	-1.16++	-1.21
23.	MCB-69 × 4190 Bt	139.15	2.37++	-52.69	4.36	1.18	-0.0227	32.20	1.05	-1.21
24.	MCB-69 × CICRBT-20031	147.04	0.10	-37.21	4.64	0.49	-0.0202	35.25	-3.58++	-1.20
25.	MCB-69 × G. Cot.10 BG-II	127.77	-0.11	-36.59	3.96	1.18	0.0227	33.85	-1.91	-0.59
26.	GTHV-13/28 × 4190 Bt	141.50	1.39	24.43	3.48	0.94	-0.0221	31.49	2.76	-0.76
27.	GTHV-13/28 × CICRBT-20031	183.51	1.42	-49.29	4.71	1.19	-0.0229	33.34	6.07	0.92
28.	GTHV-13/28 × G. Cot.10 BG-II	132.85	1.33++	-52.64	3.32	0.96	-0.0224	32.70	10.21	5.53 *
29.	GT-84 × 4190 Bt	153.94	-0.06+	-48.50	3.71	1.19	-0.0229	33.31	1.47	0.34
30.	GT-84 × CICRBT-20031	161.93	0.67++	-52.52	3.88	0.71+	-0.0229	33.94	0.53	0.05
31.	GT-84 × G. Cot.10 BG-II	186.75	0.50	-32.30	4.62	0.96	0.0224	33.05	2.04	0.37
32.	G. Cot. Hy-26-BG-II	143.87	2.06++	-52.33	3.98	1.19	-0.0229	33.27	3.32	-0.74
	Mean	138.63			3.91			32.62		

+ and ++ indicate significance of regression coefficient (b_i) from unity at 5% and 1% levels, respectively. \ and \\\ indicate significance of deviation from regression (S^2di) at 5% and 1% levels, respectively

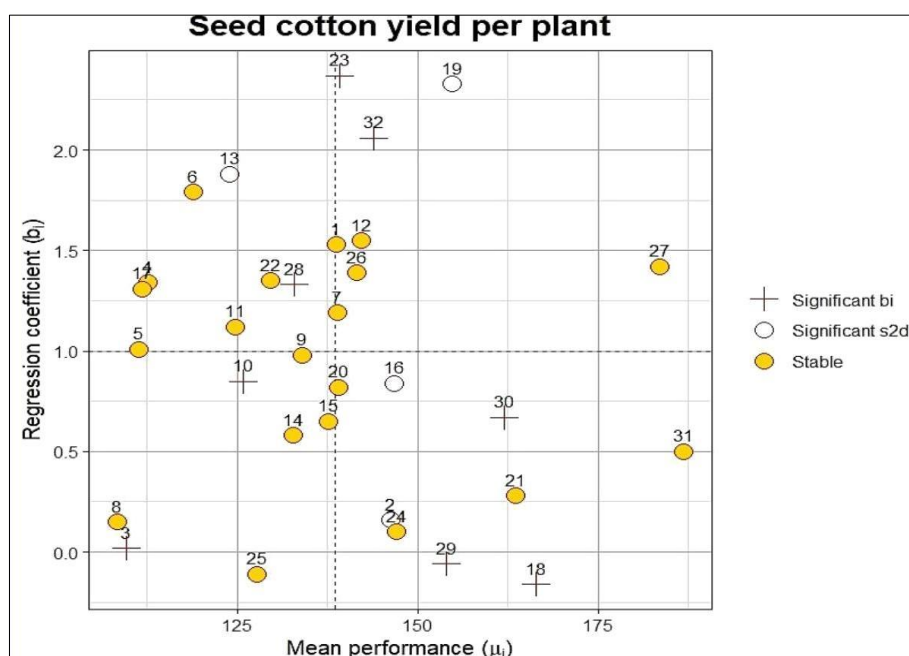


Fig 1: Graphical representation of the stability parameters for seed cotton yield per plant

For boll weight, fourteen hybrids exhibited desirable mean performance with unit regression response and non-significant deviation from regression, indicating stable performance across environments. Among these, GTHV-13/28 × CICRBT-20031, MCB-69 × CICRBT-20031 and GT-84 × G. Cot.10 BG-II were found superior (Table 5). Similarly, sixteen hybrids showed average stability for ginning outturn with desirable mean values, regression coefficients around unity and non-significant deviations from regression. The promising hybrids under this category were BC-68-2-3 × G. Cot.10 BG-II, GT-84 × CICRBT-20031 and BC-68-2-3 × CICRBT-20031 (Table 5). For lint index, sixteen hybrids were identified as stable and widely adapted across environments. Among them, GT-84 × CICRBT-20031, GT-84 × G. Cot.10 BG-II and BC-68-2-3 × CICRBT-20031 recorded superior mean performance with stable response (Table 6).

In case of upper half mean length, fourteen hybrids showed desirable mean values with regression coefficients close to

unity and non-significant deviation from regression, indicating stable fibre performance across environments. The superior hybrids identified were BC-68-1145- 42×4190 Bt, MCB-69 × 4190 Bt and BC-68-2-4 × G. Cot.10 BG-II (Table 6). For uniformity ratio, nine hybrids exhibited average stability and wider adaptability with desirable mean performance, unit regression coefficients and non-significant deviation from regression. Among these, BC-68-2-4 × CICRBT-20031, BC-68-2-4 × 4190 Bt and BC-68-1145-42 × G. Cot.10 BG-II were identified as promising stable hybrids (Table 6). Overall, none of the parents or hybrids was found stable for all the characters studied across environments, indicating differential environmental influence on trait expression. However, the hybrids identified as stable for seed cotton yield and important yield contributing traits may be utilized further in cotton breeding programmes aimed at developing widely adapted and stable high-yielding hybrids.

Table 6: Stability parameters for Lint index, Upper half mean length and Uniformity ratio in cotton

Sr. No.	Genotypes	Lint index			Upper half mean length			Uniformity ratio		
		μ_i (g)	bi	S ² di	μ_i (mm)	bi	S ² di	μ_i (%)	bi	S ² di
1.	BC-68-2-3	3.74	-2.85	0.11	26.51	3.13++	-0.12	83.83	4.27++	-0.41
2.	BC-68-2-4	4.41	1.61	-0.04	28.38	2.20	-0.08	85.08	11.73++	-0.35
3.	BC-68-1145-42	4.05	1.83	0.23 *	28.19	-3.43++	-0.06	86.22	13.87++	-0.35
4.	MCB-16-1	4.55	-2.72	0.01	28.46	0.47	-0.08	84.28	4.27	-0.19
5.	MCB-69	4.79	-1.22	-0.01	27.29	1.75	-0.03	82.86	-10.67++	-0.19
6.	GTHV-13/28	4.56	0.96	-0.02	27.68	1.80	-0.07	83.72	6.40	-0.19
7.	GT-84	4.01	1.63	0.14	26.26	1.78	-0.09	82.73	-3.20	0.09
8.	4190 Bt	4.05	-1.24	0.01	27.97	0.2	-0.02	84.64	1.07	-0.35
9.	CICRBT-20031	4.55	-2.92	0.17 *	24.77	3.91	0.10	83.50	2.13	-0.19
10.	G. Cot. 10 BG-II	4.29	-2.55++	-0.04	26.92	4.12++	-0.11	82.94	-2.13++	-0.41
11.	BC-68-2-3 × 4190 Bt	4.14	-0.56	0.07	28.20	2.53	0.42 *	84.41	-1.07	-0.35
12.	BC-68-2-3 × CICRBT-20031	4.84	1.71	-0.05	26.99	1.20	-0.08	84.64	-3.20+	-0.35
13.	BC-68-2-3 × G. Cot.10 BG-II	4.58	2.48	-0.04	26.82	1.55++	-0.13	83.84	0.12	-0.19
14.	BC-68-2-4 × 4190 Bt	4.18	-0.09	0.02	28.86	-0.88	0.65 *	85.05	16.00	0.98
15.	BC-68-2-4 × CICRBT-20031	4.4	1.65	-0.04	27.81	2.27	0.52 *	85.77	-1.07	-0.35
16.	BC-68-2-4 × G. Cot.10 BG-II	4.57	0.86	-0.05	28.42	0.43	0.32	84.73	-10.67++	-0.19
17.	BC-68-1145-42 × 4190 Bt	4.47	1.18	-0.05	28.54	-0.47	-0.08	83.40	-10.67++	-0.41
18.	BC-68-1145-42 × CICRBT-20031	4.33	6.15	0.13	27.76	1.85	-0.11	85.77	-3.20+	-0.35
19.	BC-68-1145-42 × G. Cot.10 BG-II	4.27	3.16++	-0.05	28.37	1.41	-0.05	84.63	1.07	-0.35
20.	MCB-16-1 × 4190 Bt	4.46	-0.13++	-0.05	28.74	-1.40+	-0.08	82.09	-17.07++	-0.41
21.	MCB-16-1 × CICRBT-20031	4.67	4.99	0.10	27.89	-0.99	-0.06	83.37	-6.40	-0.19
22.	MCB-16-1 × G. Cot.10 BG-II	4.78	-1.01++	-0.05	27.98	0.46	-0.12	83.25	-3.20+	-0.35
23.	MCB-69 × 4190 Bt	4.21	0.90	-0.05	28.41	-0.77	0.04	85.57	5.33+	-0.35
24.	MCB-69 × CICRBT-20031	4.98	-3.28++	-0.04	28.34	-0.95	0.00	85.75	9.60++	-0.35
25.	MCB-69 × G. Cot.10 BG-II	4.49	-1.56	-0.02	28.21	1.01	0.13	83.50	-1.07	-0.35
26.	GTHV-13/28 × 4190 Bt	4.06	2.19	-0.03	28.58	-0.24++	-0.12	86.22	13.87++	-0.35
27.	GTHV-13/28 × CICRBT-20031	4.70	5.54	0.06	27.67	1.10	0.15	83.83	4.27++	-0.41
28.	GTHV-13/28 × G. Cot.10 BG-II	4.38	8.44	0.28 *	27.21	4.19	0.01	83.83	4.27	-0.19
29.	GT-84 × 4190 Bt	4.68	1.79	0.01	28.18	0.67	0.19	85.19	10.67++	-0.41
30.	GT-84 × CICRBT-20031	5.16	-0.19	-0.01	26.72	1.75	0.29	85.19	10.67++	-0.41
31.	GT-84 × G. Cot.10 BG-II	4.89	1.81	0.03	26.21	2.05++	-0.13	83.39	-6.40	-0.41
32.	G. Cot. Hy-26-BG-II	4.64	3.43+	-0.04	27.26	-0.69	0.07	83.86	-7.47++	-0.35
	Mean	4.47			27.68			84.28		

+ and ++ indicate significance of regression coefficient (*bi*) from unity at 5% and 1% levels, respectively. \ and \\\ indicate significance of deviation from regression (*S²di*) at 5% and 1% levels, respectively.

Similar findings on stability in cotton were also reported by Gul *et al.* (2016) ^[13], Kumbhalkar *et al.* (2021) ^[14], Vavadiya *et al.* (2021), Murthy and Pradeep (2022) ^[11], Deho *et al.* (2023) ^[15], Baraki *et al.* (2024) ^[16] and Rajani and Valu (2025) ^[17].

In the present study, stability of the identified hybrids for seed cotton yield per plant was assessed along with their performance for important yield contributing traits presented in Table 7. Based on mean performance, regression coefficient (*bi*) and deviation from regression (*S²di*), four hybrids were

identified as average stable and widely adapted for seed cotton yield per plant across environments. These included GT-84×G Cot.10 BG-II (186.75 g), GTHV-13/28 × CICRBT-20031 (183.51 g), MCB-16-1 × CICRBT-20031 (163.50 g) and MCB-69 × CICRBT-20031 (147.04 g). In addition, these hybrids also exhibited desirable stability for several yield contributing traits, suggesting their potential usefulness in cotton improvement programmes aimed at developing stable and high-yielding hybrids adaptable to diverse environmental conditions.

Table 7: Average stable hybrids identified on the basis of stability criteria for seed cotton yield per plant with their per se value and their performance in terms of other characters

Hybrids	Seed cotton yield per plant (g)	Average stable	Adaptable to favourable environments	Adaptable to unfavourable environments
GT-84 × G. Cot.10 BG-II	186.75	NMPP, NSPP, WSCSH, BW, GOT, LI, UR	UHML	PH
GTHV-13/28 × CICRBT-20031	183.51	PH, NMPP, NSPP, WSCSH, BW, GOT, LI, UHML	LA, UR	-
MCB-16-1 × CICRBT-20031	163.50	NSPP, LA, WSCSH, GOT, LI, UHML, UR	NMPP,	PH, BW
MCB-69 × CICRBT-20031	147.04	NMPP, WSCSH, BW, UHML	LA, UR	PH, GOT, LI

PH= Plant height, NMPP= Number of monopodia per plant, NSPP= Number of sympodia per plant, LA= Leaf area, WSCSH= Weight of seed cotton in second harvest, BW= Boll weight, GOT= Ginning outturn, LI= Lint Index, UHML= Upper half mean length and UR= Uniformity ratio.

Conclusion

Stability analysis revealed significant effects of genotypes, environments and their interactions for seed cotton yield and its component traits, indicating differential performance across environments. None of the parents or hybrids showed ideal stability with desirable mean performance for all traits, suggesting that stability is trait-specific and difficult to achieve simultaneously. Hence, multi-environment testing is essential, while parent selection should rely on combining ability. Based on *per se* performance and stability parameters, hybrids such as GT-84 × G. Cot.10 BG-II, GTHV-13/28 × CICRBT-20031, MCB-16-1 × CICRBT-20031 and MCB-69 × CICRBT-20031 were identified as relatively stable and high yielding with average responsiveness. Based on environment indices, Talod (E₃) was found to be the most favourable environment, while Khedbrahma (E₂) was less favourable, emphasizing the strong environmental influence on trait expression.

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References

- Eberhart ST, Russell WA. Stability parameters for comparing varieties. *Crop Science*. 1966;6(1):36–40.
- Cooper M, DeLacy IH. Relationship among analytical methods used to study genotypic variation and genotype-by-environment interaction in plant breeding multi-environment. *Theoretical and Applied Genetics*. 1994;88:561–572.
- Kang MS. Using genotype-by-environment interaction for crop cultivar development. *Advances in Agronomy*. 1998;62:199–252.
- Baker RS. Genotype-environment interactions in yield of wheat. *Canadian Journal of Plant Science*. 1969;49:743–751.
- Saini DP, Ranwaha BR, Rokadia P. Stability parameters in upland cotton (*Gossypium hirsutum* L.). *Journal of Cotton Research Development*. 2008;22(1):28–30.
- Satish Y, Jain PP, Chhabra BS. Stability analysis for yield and its component traits in American cotton (*Gossypium hirsutum* L.). *Journal of Cotton Research Development*. 2009;23(2):175–182.
- Nidagundi JM, Patil SS, Salimath PM, Hegde MG. Stability studies in cotton (*Gossypium hirsutum* L.). Can stable performance of cotton genotypes in the national trial be used as reliability index in determining stable hybrids. *Crop Improvement*. 2010;37:201–207.
- Singh S, Singh VV, Chaudhary AD. Genotype × environment interaction and yield stability analysis in multi-environments. *Tropical and Subtropical Agroecosystems*. 2014;17(3):477–782.
- Patil AE, Deosarkar DB, Kalyankar SV. Impact of genotype × environment interaction on the heterosis and stability for seed cotton yield on heterozygous and homozygous genotypes in cotton. *Indian Journal of Genetics*. 2017;77(1):119–125.
- Abro S, Rajput MT, Sial MA, Deho ZA, Rizwan M. Stability analysis for seed cotton yield of newly developed upland cotton genotypes. *Advances in Agriculture and Animal Sciences*. 2021;36(2):97–100.
- Murthy KGK, Pradeep T. Influence of G × E interaction on heterobeltiosis, combining ability and stability of multiple cross derivatives of cotton (*Gossypium hirsutum* L.) amenable for High-Density Planting System. *Indian Journal of Genetics and Plant Breeding*. 2022;82(03):359–360.
- Suresh DA. Studies on heterosis, combining ability and stability for yield and fibre quality traits in intra (*Gossypium hirsutum* L. × *Gossypium hirsutum* L.) and inter specific (*Gossypium hirsutum* L. × *Gossypium barbadense* L.). 2023.
- Gul S, Khan NU, Gul R, Baloch M, Latif A, Khan IA. Genotype by environment and phenotypic adaptability studies for yield and fiber variables in upland cotton. *Journal of Animal and Plant Sciences*. 2016;26(3):776–786.
- Kumbhalkar HB, Gawande VL, Deshmukh SB, Gotmare V, Waghmare VN. Genotype × Environment interaction for seed cotton yield and component traits in upland cotton (*Gossypium hirsutum* L.). *Electronic Journal of Plant Breeding*. 2021;12(4):1209–1217.
- Deho ZA, Abro S, Rizwan M, Abro SA, Bughio H. Stability studies of newly developed cotton genotypes for seed cotton yield sown at various locations of Sindh province. *Pure and Applied Biology*. 2023;12(2):1144–1149.
- Baraki F, Gebregergis Z, Belay Y, Teame G, Gebremedhin Z, Abadi A, *et al*. Parametric and non-parametric measures to identify stable and adaptable cotton (*Gossypium hirsutum* L.) genotypes. *Journal of Natural Fibers*. 2024;21(1):2317426.
- Rajani V. Evaluating the stability of seed cotton yield and its key components over environments. *Plant Archives*. 2025;405–412.
- Sirisha ABM, Ahamed LM, Kumar PVR, Ratnakumari S, Srinivas V. Stability analysis for seed cotton yield and its component traits in upland cotton (*Gossypium hirsutum* L.). *Science Spectrum*. 2019;4(1–2):18–27.
- Vavdiya PA, Chovatia VP, Bhut NM, Vadodariya GD. G × E interactions and stability analysis for seed cotton yield and its components in cotton (*Gossypium hirsutum* L.). *Electronic Journal of Plant Breeding*. 2021;12(2):396–402.