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AMMI analysis for quality characters in upland cotton

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Abstract
The present study was carried out with forty five intra hirsutum cotton hybrids over three locations *viz*., Regional Agricultural Research Station, Lam Farm, Guntur; Agricultural Research Station, Jangamaheswarapuram and Agricultural Research Station, Darsi of Andhra Pradesh, India during *kharif* 2013-14 to study the Genotype × environment interaction on fibre quality traits like 2.5% span length, bundle strength, fibre elongation, uniformity ratio, and micronaire in cotton using Additive Main Effects and Multiplicative Interaction Model. Analysis of variance was significant for all the quality traits and environments and (G x E) components indicating the use fullness of AMMI analysis in identifying the stable genotypes. The analysis also partitioned the total G x E component into IPCA1 and Residual. Among the hybrids, BBGH-77 x BBGH-33 for bundle strength and micronaire, BBGH-77 x BBGH-1 and BBGH-3 x BGH-94 for fibre elongation and micronaire are found to be highly stable over environments and can be exploited for commercial cultivation after thorough testing and over locations and years for these important quality traits.

Keywords: cotton, AMMI, stability, quality characters

Introduction

Cotton is an important natural fibre crop of global importance cultivated in tropical and subtropical regions of the world (< 80 countries). Cotton seed coat fibres are spun into fine yarn. It belongs to the family Malvaceae and genus *Gossypium*. Cotton germplasm has 45 diploid species (2n = 26) and six allopolyploids (2n = 4x = 52). Among these species, only four species are commercially important and cultivated widely throughout the world. (*Gossypium herbaceum, G. arboretum, G. hirsutum* and *G. barbadense*). *G. hirsutum* is considered as the prime cotton species because of its fibre and yield.

In India, Cotton is lifeline of the textile industry and mainly grown by the small and middle class farmers in their marginal lands of varied soils. It is grown in varied agro climatic zones of India with the average yield of 496 kg lint per hectare indicating the low productivity of the cultivated genotypes compared to the world average yield of 775 kg lint per hectare. This necessitates the importance of sustainable cotton production practices along with high yielding genotypes for improving the productivity in Indian farming. In breeding programmes, the development of new cultivars and suitability of these genotypes to different environmental situations, are considered as important objectives but estimating the genotype x environment interaction forms the success of stable genotypes identification.

The stability of a genotype to different environmental situations is studied by using suitable biometrical technique where the environmental influence on the expression of the genotype is minimal. Thus, Genotype X environment (GxE) interaction form a major concern to plant breeders for developing improved stable cultivars suitable for over locations. The presence of GxE interactions modifies the correlation between phenotype and genotype, and makes the selection programme difficult. In the presence of significant GxE interactions, the superiority of individual genotypes across the range of environments is decided by the stability parameters and stability of a genotype indicates the consistent performance across environments. There are several methods to estimate the stability of a genotype across environments by determining GxE interaction effects. Among these, AMMI analysis is the most recent and widely exploited in different crops for the identification of stable genotypes over locations. The results of AMMI (Additive Main Effects and Multiplicative Interaction) analysis are useful in identifying the stable genotypes to specific environments which can be utilized in breeding program (Gauch and Zobel, 1997) [5]. This model was exploited in cotton by Gutierrez *et al*. (1994) [6], CruzMedina and Hernandez-Jasso (1994), El-Shaarawy (2000) [2] and Jones *et al*. (2003) [7] but the reports on the utilization of this model in India are not available for the quality parameters in cotton. Hence, the present study of stability was carried out with 45 hybrids of cotton to know the adaptability of genotypes to variable environments for quality traits.

Materials and Methods

The experiment was conducted with 45 intra-hirsutum cotton hybrids during *kharif* 2013-14 at three locations *viz*., Regional Agriculture Research Station, Lam; Agriculture Research Station, Jangamaheswarapuram and Agriculture Research Station, Darsi, of Andhra Pradesh, India. The experiments were laid in randomized block design with three replications. Each plot consisted of two rows each of 6 m length with a spacing of 120 x 60 cm. Standard package of practices were followed to maintain a good crop in the field. Observations were recorded on quality traits like bundle strength (g/tex), fibre elongation (%), uniformity ratio, fiber elongation ratio, micronaire (10^{-6}g/inch) along with seed cotton yield per plant (g). The quality traits were measured using Premier HFT 9000 V 2.1.5 SP high volume instrument. The data was subjected to analysis of variance and then taken for AMMI analysis for identification of stable genotypes.

AMMI analysis is a combination of ANOVA and principal component analysis (PCA). The AMMI statistical model was explained by Gauch (1992) [4] and can be written as

$$Y_{ij} = \mu + g_i + e_j + \sum_{k=1}^{m} \lambda_k \mu_{ik} V_{jk} + \varepsilon_{ij}$$

Where,

Y_{ij} = Mean yield of the i^{th} genotype in the j^{th} environment.

μ = Grand mean.

g_i = i^{th} genotype

e_j = j^{th} environment

k = Number of PCA axes retained in the model

λ_k = Singular value for the PCA axis, k

u_{ik} = i^{th} genotype PCA score for the axis, k

v_{jk} = j^{th} environment PCA score for the axis, k

ε_{ij} = Residual

In this model, the Genotype x Environment interaction is partitioned into a number of interaction components (IPCA) and a residual. The IPCA scores assist in understanding interaction, improving accuracy of yield estimates and increasing the probability of successfully selecting cultivars with the highest yields. In the presence of significant GE interactions, stability parameters are estimated to determine the superiority of individual genotypes across the range of environments for various quality parameters of cotton along with seed cotton yield.

Results and Discussion

Stability of a genotype in expression over environemtns is one of the important criterion in plant breeding programmes as the interaction of genotype with environment leads deviation to the predicted performance. Hence, Genotype x environment (GEI) has to be predicted well in advance before the commercial exploitation of the varieties/ hybrids. In the presence of significant GE interactions, stability parameters are estimated to determine the superiority of individual genotypes across the range of environments before their utilization.

The AMMI analysis of variance for fibre quality traits of the 45 intra hirsutum cotton genotypes tested across three environments is presented in Table 1. The results revealed that significant differences between genotypes, environments and G x E interaction for these traits indicating the presence of variability among these components and justifies the use of AMMI stability analysis for the identification of stable genotypes. A large sum of squares for environments indicated that the environments were diverse, with large differences among environmental means causing most of the variation in quality traits of cotton. The component of genotype x environment interaction was highly significant indicting the differential responses of the genotypes to the varied environmental situations. Similar results wer also reported for the larger effects of environment in G x E component by Naveed *et al*. (2007) [12], and Pretorius *et al.* (2015) [10].

The genotype x environment component was partitioned into IPCA1 and residual components. The component of IPCA1 was higher than the residual effect a for all the traits viz., 72.23% and 27.77% for 2.5 % span length; 86.71% and 13.29% for bundle strength; 71.68% and 28.32% for fibre elongation; 68.46% and 31.54% for uniformity ratio and 60.70% and 39.30%, for micronaire (10^{-6} g/inch), IPCA I and residual effect, respectively indicating the effective partition of the variability with AMMI model. I PCA 2 recorded non significant interaction for all the quality characters. Sharma *et al.* (1998) [13] also reported significant interactions in pearl millet using AMMI stability analysis.

The stability analysis using AMMI also provided with the biplot showing the main effects and principal component scores of interactions of genotypes and environments simultaneously in graphical form (Fig. 1 to 5). The hybrids evaluated at Darsi locations showed moderate to high means with low interaction effects for the trait, 2.5 % span length whereas Lam location hybrids recorded high mean with high interaction effects. For bundle strength, the hybrids at Lam location recorded high mean value with high interaction effects; while the hybrids at Jangamaheswarapuram and Darsi recorded low mean values with low interaction effects for this parameter. Darsi and Lam locations recorded high mean values with low and high interaction effects, respectively for the trait, fibre length; whereas the Jangamaheswarapuram location hybrids recorded high mean value and near to zero IPCA score indicating the stable performance of the genotypes for this trait. For uniformity ratio, the hybrids at Jangamaheswarapuram and Darsi were nearly on the same axes and recorded high mean with low interaction effects, whereas the hybrids at Lam location recorded low mean values with high interaction effects. The quality trait, Micronaire (10^{-6} g/inch), showed high mean values with high and low interaction effects, respectively, for the hybrids at Darsi and Jangamaheswarapuram whereas at Lam location, the hybrids recorded low mean values with low interaction effects.

The hybrids which recorded higher mean values than general mean with Zero IPCA score on biplot are considered as stable hybrids across all environments (Table -2). In AMMI biplot analysis the hybrid, BBGH-3 x BBGH-33 and GHL-5 x BGH-23 for 2.5 % span length (Fig 1), BBGH-26 x BBGH-33 and BBGH-77 x BBGH-33 for bundle strength (Fig 2), BBGH-77 x BBGH-1, BBGH-3 x BGH-94 and BBGH-26 x BL-7 for fibre elongation (Fig 3), BBGH-26 x BBGH-1for Uniformity ratio (Fig 4), GHL-8 x BGH-23, BBGH-77 x

BBGH-33, BBGH-77 x BBGH-1, BBGH-3 x BBGH-26, BBGH-3 x GHL-5 and BBGH-3 x BGH-94 for Micronaire (Fig 5) recorded higher mean values than general mean with Zero IPCA scores are considered to have stable performance of hybrids across all environments. Nidagundi *et al.* (2012) [9], Riaz *et al.* (2013) [12] and Reddy and Sarma (2014) [11] reported similar results in cotton for various quality traits.

The hybrids, BBGH-77 x BGH-23 for 2.5% span length, BBGH-77 x BBGH-1 for bundle strength, BBGH-3 x BBGH-26 for fibre elongation and uniformity ration, recorded the highest values for these traits but were stable over locations. Hence, they cannot be recommended for general cultivation over environments as they showed high levels of interaction with the environment.

The stable hybrids, BBGH-77 x BBGH-33 for bundle strength and micronaire, BBGH-77 x BBGH-1 and BBGH-3 x BGH-94 for fibre elongation and micronaire, can be exploited for the quality of cotton. These hybrids needs to be evaluated for their superiority and can be exploited for commercial cultivation and utilization in breeding programme for the development of desired characters.

Table 1: Analysis of variance of quality traits using AMMI stability model in cotton (*Gossypium hirsutum* L.).

Source of Variations	d.f.	2.5% span length (mm)		Bundle strength (g/Tex)		Fibre elongation (%)		Uniformity ratio		Micronaire (10^{-6} g $Inch^{-1}$)	
		Mean Squares	% explained	Mean Squares	% explained	Mean Squares	% explained	Mean Squares	% explained	Mean Squares	% explained
Trials	134.00	4.18**		135.05**		0.10*		145.14**		0.08**	
Genotypes	44.00	10.21**	80.15	2.59*	0.63	0.13**	45.01	1.50*	0.34	0.17**	65.34
Environments	2.00	13.69**	4.89	8927.90**	98.67	0.50**	7.69	9654.92**	99.28	0.36**	6.46
G×E Interaction	88.00	0.95**	14.96	1.44**	0.70	0.07**	47.30	0.84**	0.38	0.04**	28.19
PCA I	45.00	1.35**	72.23	2.45**	86.71	0.10**	71.68	1.12**	68.46	0.04**	60.70
Residual	43.00	0.54**	27.77	0.39*	13.29	0.04**	28.32	0.54**	31.54	0.03**	39.30
Pooled residual	43.00	0.54		1.44		0.07		0.54		0.04	
Error	270.00	0.09		0.26		0.01		0.09		0.01	
Total	404.00	1.45		44.97		0.04		48.20		0.03	

*, ** represents Significant at 5% and 1% levels, respectively.

Table 2: Mean performance of intra hirsutum hybrids for quality traits over locations and mean performance in cotton (*Gossypium hirsutum* L.).

S. No	Character	2.5% Span length (mm)				Bundle strength (g/Tex)				Fibre elongation (%)				Uniformity ratio				Micronaire (10^{-6}g $Inch^{-1}$)			
		Darsi	JMP	Lam	Mean	Darsi	JMP	Lam	Mean	Darsi	JMP	Lam	Mean	Darsi	JMP	Lam	Mean	Darsi	JMP	Lam	Mean
1	BBGH-77 x BBGH-3	29.78	27.43	30.12	29.11	21.51	23.89	23.2	22.87	5.21	5.69	5.23	5.38	47.23	47.22	47.08	47.18	4.56	4.83	4.56	4.65
2	BBGH-77 x BBGH-26	29.34	27.64	28.14	28.37	23.16	23.26	23.11	23.18	5.03	5.64	5.42	5.36	48.74	48.42	48.38	48.51	4.54	4.22	4.25	4.34
3	BBGH-77 x BBGH-33	32.19	28.78	28.96	29.98	23.19	24.12	23.47	23.59	5.24	5.66	5.43	5.44	49.01	48.67	48.30	48.66	5.03	5.03	4.86	4.97
4	BBGH-77 x BBGH-1	28.12	27.03	27.56	27.57	25.03	24.12	25.12	24.76	5.89	5.84	6.12	5.95	49.37	48.76	49.81	49.31	4.98	4.64	5.04	4.89
5	BBGH-77 x GHL-5	29.3	29.06	29.24	29.20	24.17	24.17	23.12	23.82	5.21	5.53	5.63	5.46	47.19	47.89	47.15	47.41	4.27	4.65	4.62	4.51
6	BBGH-77 x BL-7	32.04	31.03	34.89	32.65	23.24	23.45	23.12	23.27	5.16	5.53	5.99	5.56	47.81	47.59	47.24	47.55	4.32	4.81	4.49	4.54
7	BBGH-77 x GHL-8	28.36	27.44	29.98	28.59	19.67	20.06	20.61	20.11	5.34	5.55	5.98	5.62	48.02	48.14	48.02	48.06	4.75	4.43	4.47	4.55
8	BBGH-77 x BGH-94	32.98	31.06	32.78	32.27	23.26	23.98	23.23	23.49	5.27	5.52	5.83	5.54	47.32	49.14	49.67	48.71	4.21	4.39	4.34	4.31
9	BBGH-77 x BGH-23	33.02	34.23	35.34	34.20	22.05	21.74	23.29	22.36	5.04	5.25	5.68	5.32	47.12	49.22	47.25	47.86	4.89	4.56	4.56	4.67
10	BBGH-3 x BBGH-26	28.23	27.03	26.12	27.13	25.34	24.12	23.74	24.40	5.98	6.07	6.02	6.02	50.12	50.08	49.71	49.97	5.02	4.81	4.98	4.94
11	BBGH-3 x BBGH-33	33.23	33.02	33.02	33.09	23.48	23.89	23.32	23.56	5.31	5.79	5.33	5.48	49.76	49.35	49.42	49.51	4.05	4.30	4.02	4.12
12	BBGH-3 x BBGH-1	28.56	27.34	26.32	27.41	24.65	24.14	24.7	24.50	5.37	5.59	5.45	5.47	48.79	49.04	47.85	48.56	4.6	4.43	4.41	4.48

13	BBGH-3 x GHL-5	29.12	28.41	28.72	28.75	22.40	23.27	23.49	23.05	5.41	5.87	5.94	5.74	49.10	48.29	48.80	48.73	4.78	4.81	4.63	4.74
14	BBGH-3 x BL-7	29.98	27.96	28.07	28.67	23.26	23.19	23.42	23.29	5.49	5.38	5.11	5.33	49.02	46.49	45.30	46.94	4.61	4.79	4.83	4.74
15	BBGH-3 x GHL-8	28.38	27.26	27.96	27.87	23.98	22.3	22.9	23.06	5.21	5.32	5.05	5.19	46.34	46.66	45.08	46.03	4.86	4.66	4.87	4.80
16	BBGH-3 x BGH-94	26.89	26.98	26.12	26.66	23.45	23.26	22.56	23.09	5.73	5.67	6.01	5.80	49.66	48.23	48.78	48.89	4.76	4.79	4.56	4.70
17	BBGH-3 x BGH-23	32.98	31.12	32.78	32.29	21.78	21.76	21.85	21.80	5.07	5.51	4.91	5.16	47.87	47.34	47.60	47.60	4.55	4.61	4.25	4.47
18	BBGH-26 x BBGH-33	31.31	28.78	27.98	29.36	24.33	23.70	24.57	24.20	5.42	5.50	5.13	5.35	47.33	48.31	46.67	47.44	4.61	4.11	4.56	4.43
19	BBGH-26 x BBGH-1	31.02	29.56	28.02	29.53	23.21	24.67	23.51	23.80	5.31	5.58	5.98	5.62	49.00	48.10	47.61	48.24	4.87	4.38	4.21	4.49
20	BBGH-26 x GHL-5	29.89	30.12	28.53	29.51	22.22	22.01	22.56	22.26	5.43	5.28	5.82	5.51	47.21	47.77	46.34	47.11	4.59	4.47	4.13	4.40
21	BBGH-26 x BL-7	28.98	27.99	27.65	28.21	22.47	22.93	22.42	22.61	5.94	5.78	6.04	5.92	48.97	47.31	43.3	46.53	4.57	4.53	4.44	4.51
22	BBGH-26 x GHL-8	28.19	28.02	27.12	27.78	23.68	22.93	23.54	23.38	5.28	5.63	5.99	5.63	45.93	44.12	43.14	44.40	4.53	4.42	4.12	4.36
23	BBGH-26 x BGH-94	27.89	27.67	26.12	27.23	24.56	23.89	23.01	23.82	5.43	5.54	6.06	5.68	48.26	48.31	45.23	47.27	5.03	4.75	4.65	4.81
24	BBGH-26 x BGH-23	28.32	28.97	27.12	28.14	23.12	21.87	21.09	22.03	5.23	5.46	5.86	5.52	48.48	48.27	46.12	47.62	4.89	4.65	4.10	4.55
25	BBGH-33 x BBGH-1	28.89	27.89	27.12	27.97	23.49	23.75	23.93	23.72	5.99	5.45	5.93	5.79	48.12	46.81	45.98	46.97	4.12	4.23	4.03	4.13
26	BBGH-33 x GHL-5	30.12	28.98	28.29	29.13	22.29	22.9	23.18	22.79	5.23	5.20	5.46	5.30	49.00	49.22	47.23	48.48	4.54	4.32	4.59	4.48
27	BBGH-33 x BL-7	32.31	32.78	33.89	32.99	23.73	23.38	23.39	23.50	5.78	5.36	5.24	5.46	49.38	49.22	49.59	49.40	4.43	3.98	3.80	4.07
28	BBGH-33 x GHL-8	29.78	29.56	28.32	29.22	21.23	22.89	23.47	22.53	5.48	5.31	4.98	5.26	46.89	48.11	48.06	47.69	3.98	4.01	3.87	3.95
29	BBGH-33 x BGH-94	28.56	29.21	27.56	28.44	23.12	21.71	22.55	22.46	5.45	5.53	4.97	5.32	47.89	48.11	44.78	46.93	4.03	4.78	4.45	4.42
30	BBGH-33 x BGH-23	34.12	32.12	30.89	32.38	23.29	22.86	23.48	23.21	5.87	5.46	5.13	5.49	49.26	48.78	45.39	47.81	4.24	4.49	4.09	4.27
31	BBGH-1 x GHL-5	28.98	28.43	27.8	28.40	22.89	22.19	21.23	22.10	5.95	5.19	5.13	5.42	49.02	47.50	45.05	47.19	4.89	4.39	4.01	4.43
32	BBGH-1 x BL-7	29.89	28.04	28.39	28.77	21.25	21.86	21.59	21.57	5.56	5.53	6.09	5.73	49.91	49.28	49.53	49.57	4.43	4.53	4.09	4.35
33	BBGH-1 x GHL-8	30.21	27.89	28.19	28.76	23.44	23.15	23.55	23.38	5.45	5.67	5.22	5.45	49.17	48.48	45.40	47.68	4.84	5.04	4.72	4.87
34	BBGH-1 x BGH-94	27.12	26.34	28.26	27.24	23.65	22.17	22.37	22.73	5.54	6.03	5.99	5.85	49.02	47.50	47.12	47.88	4.76	4.89	5.03	4.89
35	BBGH-1 x BGH-23	29.34	28.03	29.89	29.09	22.22	22.29	22.54	22.35	5.24	5.21	5.40	5.28	49.73	48.94	48.80	49.16	4.43	4.56	4.01	4.33
36	GHL-5 x BL-7	28.97	28.87	29.48	29.11	23.28	22.10	22.34	22.57	5.45	5.36	5.34	5.38	46.34	48.64	48.01	47.66	4.76	4.51	4.60	4.62
37	GHL-5 x GHL-8	28.78	27.43	30.03	28.75	23.69	24.70	24.38	24.26	5.21	5.13	5.41	5.25	49.16	47.52	49.34	48.67	4.78	4.64	4.13	4.52
38	GHL-5 x BGH-94	30.12	27.38	28.93	28.81	23.89	22.00	22.10	22.66	5.04	5.11	5.43	5.19	49.00	48.45	48.74	48.73	4.83	4.43	4.43	4.56
39	GHL-5 x BGH-23	33.23	33.13	33.45	33.27	21.89	22.05	21.57	21.84	5.20	5.23	5.31	5.25	48.78	47.46	47.59	47.94	4.31	4.39	4.30	4.33
40	BL-7 x GHL-8	31.04	28.74	28.89	29.56	20.43	19.98	21.28	20.56	5.67	5.42	5.62	5.57	49.00	48.15	48.19	48.45	4.47	4.56	4.73	4.59
41	BL-7 x BGH-94	30.02	27.92	28.87	28.94	23.13	22.41	22.52	22.69	5.09	5.83	5.76	5.56	47.19	48.61	47.95	47.92	4.58	4.67	4.49	4.58
42	BL-7 x BGH-23	30.12	27.67	28.92	28.90	22.89	22.24	21.59	22.24	5.02	5.39	5.89	5.43	46.70	46.95	47.29	46.98	4.53	4.51	4.21	4.42
43	GHL-8 x BGH-94	27.89	27.56	28.78	28.08	20.98	22.29	20.71	21.33	4.98	5.21	5.81	5.33	48.70	48.16	48.07	48.31	4.65	4.67	4.57	4.63
44	GHL-8 x BGH-23	29.14	27.43	28.78	28.45	22.42	23.15	22.19	22.59	5.01	5.43	5.83	5.42	47.97	47.52	47.86	47.78	4.98	4.87	4.86	4.90
45	BGH-94 x BGH-23	28.98	27.12	32.12	29.41	25.63	24.89	23.23	24.58	5.23	5.28	5.94	5.48	48.32	47.33	47.89	47.85	4.56	4.79	4.37	4.57
	Overall Mean				29.32				22.93				5.50				47.94				4.53

JMP: Jangamaheswarapuram

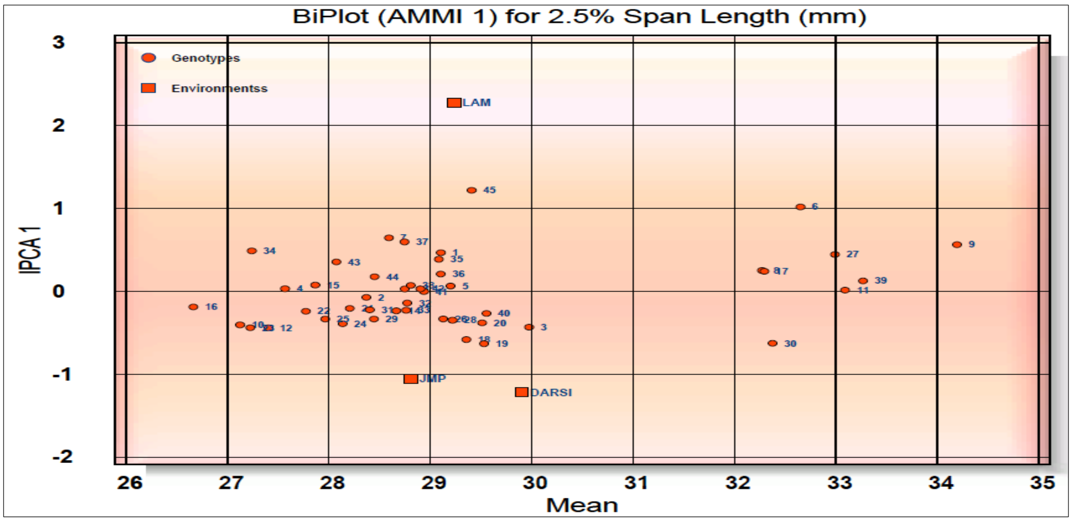

Fig 1: AMMI Biplot of 45 intra-hirsutum cotton hybrids evaluated for 2.5% span length at three locations of Andhra Pradesh, India

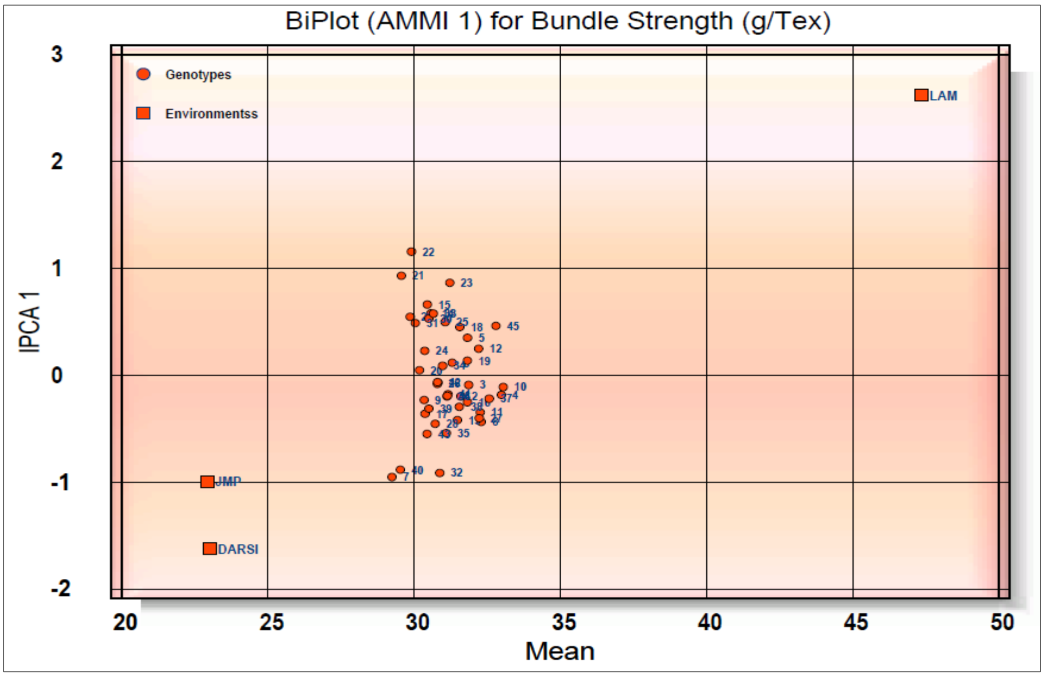

Fig 2. AMMI Biplot of 45 intra-hirsutum cotton hybrids evaluated for bundle strength at three locations of Andhra Pradesh, India

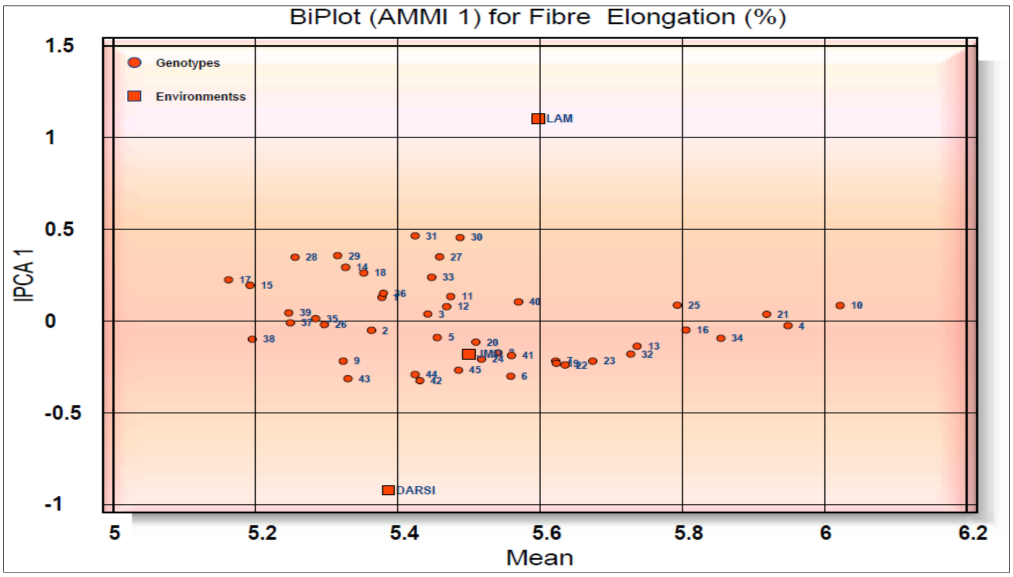

Fig 3: AMMI Biplot of 45 intra-hirsutum cotton hybrids evaluated for fibre elongation at three locations of Andhra Pradesh, India

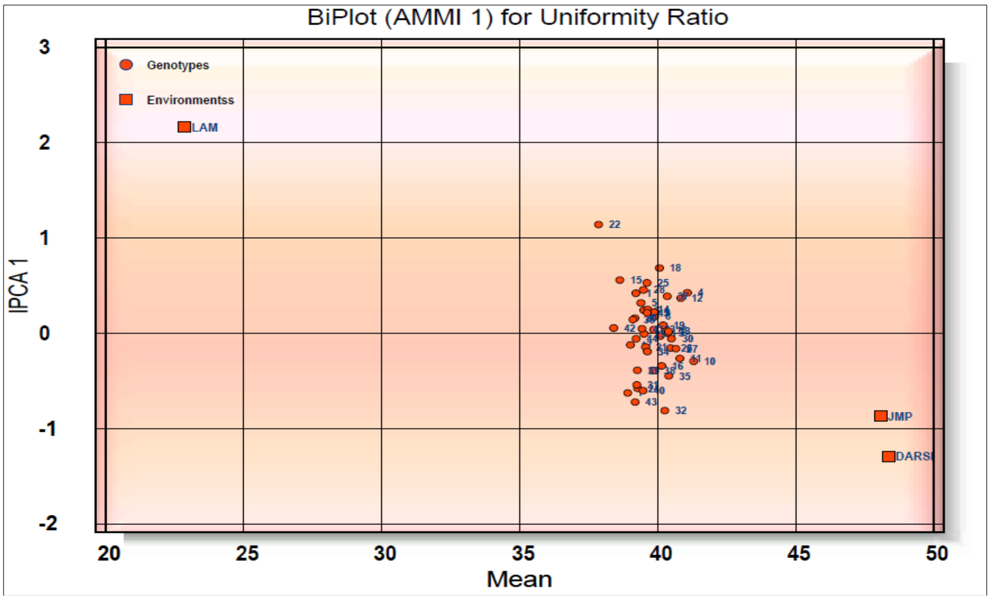

Fig 4. AMMI Biplot of 45 intra-hirsutum cotton hybrids evaluated for uniformity ratio at three locations of Andhra Pradesh, India

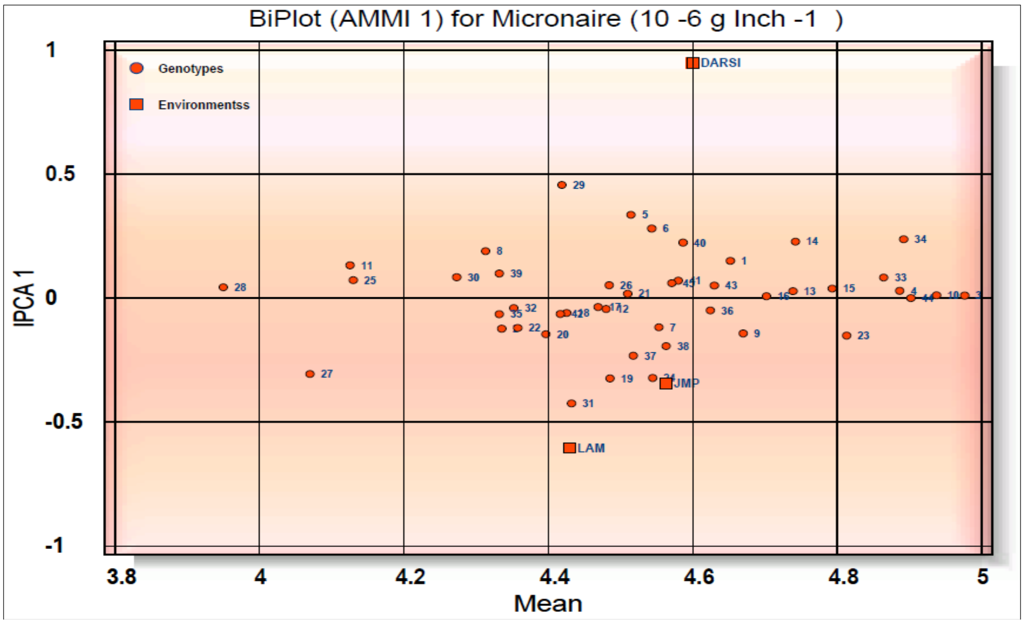

Fig 5. AMMI Biplot of 45 intra-hirsutum cotton hybrids evaluated for micronaire at three locations of Andhra Pradesh, India

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