Electronic Journal of Plant Breeding, 8(1): 216-225 (March 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00031.X

Research Article

Stability of parents and their F_1 populations of *tossa* jute under different environments

V.A. Kale* and S.K. Roy
Department of Genetics and Plant Breeding, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal
E-mail: vakale86@gmail.com

(Received: 18 July 2016; Revised: 09 March 2017; Accepted: 14 March 2017)

Abstract
Nine tossa jute parents and their 36 F_1's produced through 9 x 9 half diallel cross, were raised in five environments (five different dates of sowing) *viz*. 11th, 18th and 25th April and 2nd and 9th May, 2012, in a randomized block design with three replications. The nine parents along with their 36 F_1's were evaluated for fibre yield and quality traits at the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal during the pre-kharif and kharif seasons of 2012. The objectives of the study were to estimate the stability of the 36 F_1's and the 9 parents for fibre yield and quality traits under different environments. The variance due to G × E showed significant interaction for all the traits except fibre percentage, indicating differential response of genotypes to different environments. Among the nine parents and 36 crosses, the parent (JRO 128) and cross (OIN 574 × JRO 128) were well adapted to all the five environments. The parents JRO 620 and JRO 878 for fibre yield and OIN 028 for fibre fineness and crosses OIJ 015 × OIN 028, OIJ 015 × OIJ 267, OIJ 015 × JRO 878, OIN 574 × JRO 878, OIN 580 × OIJ 267, OIN 580 × JRO 878 and JRO 620 × OIJ 267 for fibre yield, OIN 028 × OIN 580, OIN 580 × JRO 128 and JRO 128 × JRO 878 for fibre tenacity and OIN 217 × OIN 574 for fibre fineness, were stable under unfavourable environments. The crosses OIJ 015 × OIN 574 and OIN 028 × JRO 878 were found to be adaptable to favourable environments for both fibre yield per hectare and fibre tenacity. The parent JRO 620 and the crosses OIJ 015 × JRO 878, OIN 574 × OIN 580 and JRO 620 × JRO 878 for fibre yield, the parent JRO 128 and the crosses OIJ 015 × OIN 574 and OIN 028 × JRO 878 for fibre tenacity and the parent JRO 620 and the crosses OIN 028 × OIN 574, OIN 028 × JRO 878, OIN 580 × OIJ 267 and OIJ 267 × JRO 128 for fibre fineness, performed well in all the five environments on the basis of AMMI 1 and AMMI 2 biplot.

Key words
Jute, stability, G × E interaction, AMMI analysis, adaptation

Introduction

Jute is one of the most affordable natural fibres and is second only to cotton in amount produced and in variety of uses of vegetable fibres. Plant breeding aims to improve crop production either within a given macro environment or in a wide range of growing conditions. An understanding of environmental and genotypic causes of G × E interaction is important at all stages of plant breeding. This can also be used to establish breeding objectives to identify ideal test conditions, and to formulate recommendations for areas of optimal cultivar adaptation (Jackson *et al*., 1998).

The concept of stability has been defined in several ways and several biometrical methods, including univariate and multivariate ones, have been developed to assess stability (Lin and Binns, 1988; Becker and Leon, 1988; Crossa, 1990 and Mevlut *et al*., 2005). Bernardo (2002) and Eberhart and Russell (1966) stated that stability can be assessed in many ways, the more common being a regression of genotype performance on an environmental index. A number of statistical methods are designed to evaluate phenotypic stability. The additive main effect and multiplicative interaction (AMMI) model is effective for gaining accuracy in stability analysis. The AMMI is the first choice when main effects and interaction are both important (Zobel *et al*., 1988). Creation of variability for fibre yield and quality was done by diallel cross and the present study focussed only on the stability of the parents and their F_1 populations.

Materials and methods

The nine parents namely OIJ 015, OIN 028, OIN 217, OIN 574, OIN 580, JRO 620, OIJ 267, JRO 128 and JRO 878 and their 36 F_1's obtained from a 9 x 9 half diallel cross, were raised in five environments (five different dates of sowing) viz. 11th April (E_1), 18th April (E_2), 25th April (E_3), 2nd May (E_4) and 9th May (E_5) in 2012, in a randomized block design with three replications, in rectangular plots of size 1.5×1 m^2 area, in which there were five rows of 1 m length. The row to row and plant to plant spacing was 30 cm and 10 cm, respectively. The experiment site was Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal. The evaluation for stability of fibre yield and quality traits under different environments was done as per Eberhart and Russell (1966) and AMMI Analysis.

The observations were recorded on six yield atributing traits namely plant height (cm), basal diameter (mm), green weight (quintal/hectare), stick weight (quintal/hectare), fibre percentage per plant (%) and fibre yield (quintal/hectare) and two quality traits namely fibre tenacity and fibre fineness. The data was recorded from five randomly selected plants in each replication for the traits plant height, basal diameter and fibre percentage per plant and the two quality traits viz. fibre tenacity (g/tex) and fibre fineness (tex). The data for the other traits namely green weight, stick weight and fibre yield was recorded per plot and converted into quintal per hectare (q/ha). The two quality traits namely fibre tenacity and fibre fineness were recorded by the instruments namely Fibre Bundle Strength Tester and Airflow Fineness Tester from ICAR-NIRJAFT (Tallygunj, West Bengal). Although several yield attributing traits were selected but finally the stability was studied in detail for the trait fibre yield (q/ha) and the two quality traits namely fibre tenacity and fibre fineness. The statistical analysis for the stability was done by using the software "Windostat".

Results and discussion

Prior to pooled analysis of the data, the Barlett's chi-square test was done to test the homogeneity of error variances of the five different environments. The chi-square test was found to be significant due to which direct pooling of data from the different environments was not possible as the error variances of the different environments were differing significantly for all the characters under study. Hence the data was $\log_e$ transformed and Barlett's chi-square test was again done with the transformed data, which showed non significant differences between the error variances of the five environments. Subsequently all the analysis was carried out using the $\log_e$ transformed values of the data.

The pooled analysis of variance with respect to all the eight traits under study revealed that the variance due to environment was significant for all the traits which indicated the distinct and differential effect of the different dates of sowing conditions (Table 1). The variance for genotypic effect was also highly significant for all the traits except green weight, indicating thereby differential response of the genotypes selected for the study. The variance due to G × E has shown significant interaction for all the traits except fibre percentage, indicating differential response of genotypes to different environments. These results are in line with the findings obtained by Alam (1987) for plant height, basal diameter, green weight, stick weight and fibre yield and Subbalakshmi *et al.* (1992) for basal diameter. Highly significant mean squares due to environment + (genotype × environment) interactions for all the traits except fibre fineness revealed that the genotype interacted considerably with environmental conditions that existed under different dates of sowing. Significant mean squares due to environment (linear) indicated considerable difference among environments and their predominant effects on all the traits. Pooled deviation was significant for all the traits except fibre percentage, which indicated the importance of non-linear components in the manifestation of G × E interaction of these traits. A similar finding for importance of non-linear components was made by Sinhamahapatra and Ghoshdastidar (1989) in *C. capsularis*. Significant G × E interaction (linear) components against pooled error for fibre percentage and fibre tenacity revealed that linear regression was the major component responsible for differences in stability whereby the performance can be predicted for these traits with some reliance under different environments, however, for the unpredicted traits, prediction can be made by considering the stability parameter of individual genotypes.

Among the nine parents and 36 crosses, the parent (JRO 128) and cross (OIN 574 × JRO 128) were well adapted to all environments (Table 2 & 3), as the higher mean for fibre yield per hectare than population mean, regression coefficient was near to unity and S^2di was non-significant. Based on the mean performance, regression coefficient (bi) values and deviation from regression values, some of the genotypes and crosses have been identified to suit with stability of performance under unfavourable environments with respect to fibre yield and they are parents viz. JRO 620 and JRO 878 and crosses viz. OIJ 015 × OIN 028, OIJ 015 × OIJ 267, OIJ 015 × JRO 878, OIN 574 × JRO 878, OIN 580 × OIJ 267, OIN 580 × JRO 878 and JRO 620 × OIJ 267 and in respect of quality traits, crosses viz. OIN 028 × OIN 580 and OIN 580 × JRO 128 for fibre tenacity and the parent OIN 028 and cross OIN 217 × OIN 574 for fibre fineness. Khandakar *et al.* (1990) earlier reported that fibre yield and stability were inversely related in both the species of jute. The crosses, OIJ 015 × OIN 574 and OIN 028 × JRO 878 were found to be adaptable for favourable environments for both fibre yield per ha and fibre tenacity, whereas, none of the crosses were found for fibre fineness.

The linear regression model of Eberhart and Russell (1966) is most frequently used for G × E interaction study and in this model a stable genotype should have low deviation from linear regression (S^2di). So many genotypes having very high yield potential often get rejected due to high S^2di over the range of environments. Thus, a genotype showing high positive interaction at certain environments and negative interaction at others is likely to show high S^2di and would be classified as unstable. AMMI analysis (Zobel et al., 1988 and Gauch, 1992) gives estimate of total G × E interaction effect of each genotype and also further partitions it into interaction effects due to individual environments. Low G×E interaction of a genotype indicates stability of the genotype over the range of environments. A genotype showing high positive interaction in an environment obviously has the ability to exploit the agroecological or agro-management conditions of the specific environment and is therefore best suited to that environment. AMMI analysis permits estimation of interaction effect of a genotype in each environment and it helps to identify genotypes best suited for specific environmental conditions. Though analysis of G × E interaction of multilocational yield data in AMMI model have been reported by Mahalingam *et al*. (2006) and Naveed *et al*. (2007) in rice, Mohammadi *et al*. (2007) in wheat, Shinde *et al.* (2002) in pearl millet and few other crops but such reports in jute is lacking.

The analysis of variance of AMMI (Table 4) showed that the mean sum of squares due to genotypes, environments and genotype x environment interaction were significant, indicating broad range of diversity existed among genotypes. Significance of the environments indicated distinctness of intrinsic factors in different environment. The significance exhibited by G x E interaction indicated that each of the genotype interacted differentially in various environment tested. The first principal component factor had a high contribution to the interaction sum of squares while the residual is small. This indicates that one fundamental factor affects G × E interaction, which could be either genotypic or environmental in nature. The residual sum of square of AMMI for fibre yield and two quality traits were non-significant with minimum residual mean sum of square and demonstrate a greater accuracy of the model.

In AMMI 1 biplot, the IPCA 1 scores of entries and environments are plotted against their respective means for fibre yield, fibre tenacity and fibre fineness and presented in Fig. 1, 3 and 5, respectively, which revealed that the interactions of environments are highly varying, while E_4 was a favourable environment for fibre yield and unfavourable for fibre tenacity. The environments E_2 and E_5 were unfavourable for fibre fineness. The entries which had high mean values and low interaction were JRO 620 (6), JRO 128 (8), OIJ 015 × OIJ 267 (15), OIJ 015 × JRO 878 (17), OIN 574 × OIN 580 (31) and JRO 620 × JRO 878 (42) for fibre yield, JRO 128 (8), OIJ 015 × OIN 574 (12) and OIN 028 × JRO 878 (24) for fibre tenacity and JRO 620 (6), OIN 028 × OIN 574 (19), OIN 028 × JRO 878 (24), OIN 217 × JRO 620 (27), OIN 580 × OIJ 267 (37) and OIJ 267 × JRO 128 (43) for fibre fineness and hence they are recommended for all the environments under study. The entries that had high mean and positive interaction were JRO 878 (9) and OIN 580 × JRO 620 (36) for fibre yield, JRO 128 (8), OIJ 015 × OIN 574 (12), OIN 028 × JRO 878 (24) and OIJ 267 × JRO 878 (44) for fibre tenacity and OIN 028 × JRO 620 (21), OIN 217 × JRO 878 (30), OIN 580 × JRO 620 (36), OIN 580 × JRO 878 (39) and JRO 620 × OIJ 267 (40) for fibre fineness, are suited to favourable environments. Conversely, the entries OIN 574 × JRO 878 (35), OIN 580 × OIJ 267 (37), OIN 580 × JRO 878 (39), JRO 620 × OIJ 267 (40) and JRO 128 × JRO 878 (45) for fibre yield, JRO 878 (9), OIN 028 × OIN 574 (19), OIN 028 × OIJ 267 (22), OIN 580 × JRO 128 (38) and JRO 128 × JRO 878 (45) for fibre tenacity and JRO 878 (9), OIJ 015 × OIN 574 (12), OIJ 015 × OIJ 267 (15), OIN 028 × OIN 580 (20), OIN 574 × JRO 878 (35) and OIJ 267 × JRO 878 (44) for fibre fineness with high mean and negative interaction, were found to be suited for unfavourable environments. Among those entries none of them were found to be suited for all the environments, favourable environments and unfavourable environments for fibre yield along with quality traits except entry number 45 (JRO 128 × JRO 878) suited for unfavourable environments for fibre yield and fibre tenacity.

Distribution of entry point in the AMMI 2 biplot for fibre yield, fibre tenacity and fibre fineness as presented in Fig. 2, 4 and 6, revealed that the entries which scattered away from the origin which were JRO 128 (8), JRO 878 (9), OIJ 015 × OIN 217 (11), OIJ 015 × OIN 580 (13), OIJ 015 × OIJ 267 (15), OIJ 015 × JRO 128 (16), OIN 028 × OIN 574 (19), OIN 028 × OIN 580 (20), OIN 028 × OIJ 267 (22), OIN 028 × JRO 128 (23), OIN 028 × JRO 878 (24), OIN 217 × OIN 574 (25), OIN 217 × JRO 620 (27), OIN 217 × OIJ 267 (28), OIN 580 × JRO 128 (38), OIN 580 × JRO 878 (39), JRO 620 × OIJ 267 (40), JRO 620 × JRO 128 (41), OIJ 267 × JRO 128 (43), OIJ 267 × JRO 878 (44) and JRO 128 × JRO 878 (45) for fibre yield, OIN 580 (5), JRO 878 (9), OIJ 015 × JRO 878 (17), OIN 028 × JRO 620 (21), OIN 217 × JRO 620 (27), OIN 217 × JRO 128 (29), OIN 217 × JRO 878 (30), OIN 574 × OIN 580 (31) and OIN 574 × JRO 620 (32) for fibre tenacity and OIJ 015 × OIN 217 (11), OIN 217 × JRO 620 (27), OIN 574 × JRO 620 (32), OIN 574 × JRO 128 (34), OIN 574 × JRO 878 (35) and JRO 128 × JRO 878 (45) for fibre fineness, which indicated that these entries were more sensitive to environmental interactive forces. Remaining entries which were scattered close to the origin, indicated minimal interaction of these entries with environments. The entries OIN 217 × OIN 574 (25), OIN 580 × JRO 878 (39) and JRO 620 × OIJ 267 (40) for fibre yield, OIN 580 (5) for fibre tenacity and OIN 217 × OIJ 267 (28) and OIN 574 × JRO 878 (35) for fibre fineness performed well in early date of sowing (E_1). Thus, the entries JRO 620 (6), OIJ 015 × JRO 878 (17), OIN 574 × OIN 580 (31) and JRO 620 × JRO 878 (42) for fibre yield, JRO 128 (8), OIJ 015 × OIN 574 (12) and OIN 028 × JRO 878 (24) for fibre tenacity and JRO 620 (6), OIN 028 × OIN 574 (19), OIN 028 × JRO 878 (24), OIN 580 × OIJ 267 (37) and OIJ 267 × JRO 128 (43) for fibre fineness performed well in all the five environments on the basis of AMMI 1 and AMMI 2 biplot.

Acknowledgement

The authors are thankful to the Head of the Department of Genetics and Plant Breeding, Dean Faculty of Agriculture, Directorate of Research and All India Network Project on Jute & Allied Fibres, Uttar Banga Krishi Viswavidylaya, for providing guidance and all the facilities required for the conduction of the experiment.

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Table 1. Analysis of variance for different traits over five environments in tossa jute

Source of variation	df	Mean sum of squares							
		Plant height (cm)	Basal diameter (mm)	Green weight (q/ha)	Stick weight (q/ha)	Fibre %	Fibre yield (qt/ha)	Fibre tenacity (g/tex)	Fibre Fineness (tex)
Rep within env.	10	0.001	0.008	0.006	0.047	0.02*	0.034	0.002	0.003
Genotypes	44	0.005**	0.007**	0.019	0.051**	0.02**	0.032*	0.022**	0.141**
Env. + (geno. × env.)	180	0.007**	0.051**	0.084**	0.164**	0.015*	0.070**	0.016**	0.040
Environments	4	0.201**	2.037**	2.964**	6.257**	0.132**	2.237**	0.292**	0.359**
Geno. × env.	176	0.002**	0.006**	0.019**	0.026**	0.013	0.021**	0.010**	0.033**
Env. (linear)	1	0.805**	8.147**	11.857**	25.028**	0.527**	8.949**	1.168**	1.435**
Geno. × env. (linear)	44	0.002	0.005	0.022	0.024	0.017*	0.019	0.012*	0.033
Pooled deviation	135	0.002**	0.007**	0.018**	0.026**	0.011	0.021**	0.008**	0.032**
Pooled error	440	0.001	0.002	0.004	0.011	0.011	0.013	0.002	0.003
Total	224	0.006	0.043	0.072	0.142	0.017	0.063	0.017	0.060

*, ** significant at 5 and 1 per cent level, respectively

Table 2. Mean performance and stability parameters of parents and F_1's for fibre yield and quality traits

Parents/F_1's	Fibre yield (qt/ha)			Fibre tenacity (g/tex)			Fibre fineness (tex)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
OIJ 015	3.52	1.03	0.04*	3.00	1.27	0.00*	0.44	0.23	0.02**
OIN 028	3.53	0.96	0.02	2.98	1.77	0.00	0.78	0.20	0.00
OIN 217	3.40	0.94	-0.01	2.97	1.19	0.01**	0.45	1.14	0.02**
OIN 574	3.68	1.09	0.00	3.05	1.35	0.00	0.47	0.37	0.01*
OIN 580	3.47	0.89	-0.01	3.02	-0.22	0.00	0.66	1.04	0.01**
JRO 620	3.72	0.65	-0.01	2.94	0.50	0.00	1.00	0.79	0.03**
OIJ 267	3.60	1.07	0.00	3.01	1.14	0.00	0.65	0.72	0.04**
JRO 128	3.66	0.98	0.00	3.13	1.49	0.00*	1.09	0.26	-0.00
JRO 878	3.78	0.71	0.01	3.17	0.00	0.02**	0.91	-0.25	0.03**
OIJ 015 × OIN 028	3.62	0.66	-0.01	2.97	1.61	0.01**	0.79	1.05	0.00
OIJ 015 × OIN 217	3.58	1.03	0.01	3.03	0.58	0.01*	0.62	2.61	0.03**
OIJ 015 × OIN 574	3.63	1.07	0.00	3.14	1.15	0.00	0.81	1.07	0.05**
OIJ 015 × OIN 580	3.58	0.72	0.01	2.99	1.68	0.01*	0.77	0.23	0.05**
OIJ 015 × JRO 620	3.61	0.88	-0.01	3.04	0.88	0.00	0.76	2.34	0.06**
OIJ 015 × OIJ 267	3.68	0.69	0.01	3.05	0.75	0.01**	0.85	0.63	0.04**
OIJ 015 × JRO 128	3.58	0.96	0.02	3.03	0.82	0.02**	0.61	0.29	0.01*
OIJ 015 × JRO 878	3.70	0.58	-0.01	3.06	1.27	0.01**	0.67	0.61	0.01**
OIN 028 × OIN 217	3.62	1.22	-0.01	3.05	0.95	0.00	0.61	2.53	0.01**
OIN 028 × OIN 574	3.57	0.95	0.06**	3.26	0.08	0.00*	0.94	1.63	0.01**
OIN 028 × OIN 580	3.53	1.16	0.05**	3.10	0.32	0.00	0.89	-0.64	0.02**
OIN 028 × JRO 620	3.54	1.76*	-0.01	3.07	0.50	0.02**	0.97	1.65	0.03**
OIN 028 × OIJ 267	3.62	1.78	0.03*	3.13	0.52	0.01**	0.71	0.00	0.04**
OIN 028 × JRO 128	3.47	1.56	0.02	3.03	1.24	0.00	0.75	1.08	0.01**
OIN 028 × JRO 878	3.63	1.02	0.01	3.16	1.39	0.00	0.99	1.21	0.02**
OIN 217 × OIN 574	3.56	0.79	0.01	2.97	2.03	0.01**	0.57	-1.33*	-0.00
OIN 217 × OIN 580	3.67	1.11	-0.01	3.05	1.16	0.01**	0.89	0.97	0.03**
OIN 217 × JRO 620	3.55	1.21	0.00	3.03	-0.27	0.02**	0.89	1.05	0.05**
OIN 217 × OIJ 267	3.58	0.68	0.03*	2.95	1.69	0.01**	0.52	-1.55	0.04**
OIN 217 × JRO 128	3.56	1.47	-0.01	3.07	2.33	0.00*	0.72	0.59	0.10**
OIN 217 × JRO 878	3.61	1.38	-0.01	3.01	1.96	0.03**	0.84	2.22	0.01**
OIN 574 × OIN 580	3.75	1.04	-0.01	3.09	0.71	0.01**	0.80	2.57	0.02**
OIN 574 × JRO 620	3.59	0.99	0.00	3.01	2.66	0.01*	0.56	2.28	0.08**
OIN 574 × OIJ 267	3.59	1.44	0.00	3.04	1.70	0.00*	0.58	1.82	0.03**
OIN 574 × JRO 128	3.68	0.99	-0.01	3.05	0.21	0.01**	0.77	2.61	0.04**
OIN 574 × JRO 878	3.69	0.87	0.00	3.03	1.14	0.01**	0.85	1.09	0.08**
OIN 580 × JRO 620	3.74	1.21	0.00	3.03	0.41	0.01**	0.86	1.61	0.05**
OIN 580 × OIJ 267	3.69	0.57	0.01	3.06	0.47	0.01**	0.97	0.22	0.01**
OIN 580 × JRO 128	3.53	1.07	0.01	3.16	0.47	0.00	0.89	1.44	0.03**
OIN 580 × JRO 878	3.75	0.61	0.01	2.97	0.65	0.02**	0.85	1.88	0.02**
JRO 620 × OIJ 267	3.63	0.61	-0.01	3.03	0.25	0.02**	1.02	1.65	0.01**
JRO 620 × JRO 128	3.61	0.54	0.01	3.08	1.31	0.01**	0.70	2.50	0.04**
JRO 620 × JRO 878	3.64	1.40	0.02*	3.06	2.02	0.00	0.89	1.68	-0.00
OIJ 267 × JRO 128	3.54	0.51	-0.01	3.08	-0.04	0.01**	0.88	1.33	0.01**
OIJ 267 × JRO 878	3.53	1.09	0.06**	3.12	1.37	0.00	1.08	-0.26	0.03**
JRO 128 × JRO 878	3.70	1.09	0.02	3.14	0.54	0.01*	0.96	-0.15	0.06**
Mean	**3.61**			**3.05**			**0.79**		
SE (mean)	**0.07**			**0.05**			**0.09**		

* Significant at 5% level, ** significant at 1% level.; The mean values of the traits are the $\log_e$ transformed values on the basis of which the bi and the S^2di values have been calculated

Electronic Journal of Plant Breeding, 8(1): 216-225 (March 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00031.X

Table 3. Stability status of tossa jute parents and crosses under five environments on the basis of mean performance, regression coefficient and deviation from linear regression for fibre yield and quality traits

Stability	Fibre yield (qt/ha)		Fibre tenacity (g/tex)		Fibre Fineness (tex)	
	Parents	Crosses	Parents	Crosses	Parents	Crosses
Well adapted to all environments (Mean>Population Mean, bi=1 and S^2di=0)	JRO 128	OIN 574 × JRO 128	-	-	-	-
Specifically adapted to favourable (rich) environments (Mean>Population Mean, bi>1 and S^2di=0)	OIN 574	OIJ 015 × OIN 574 OIN 028 × OIN 217 OIN 028 × JRO 878 OIN 217 × OIN 580 OIN 574 × OIN 580 OIN 580 × JRO 620 JRO 128 × JRO 878	-	OIJ 015 × OIN 574 OIN 028 × JRO 878 JRO 620 × JRO 878 OIJ 267 × JRO 878	-	-
Specifically adapted to unfavourable (poor) environments (Mean>Population Mean, bi<1 and S^2di=0)	JRO 620 JRO 878	OIJ 015 × OIN 028 OIJ 015 × OIJ 267 OIJ 015 × JRO 878 OIN 574 × JRO 878 OIN 580 × OIJ 267 OIN 580 × JRO 878 JRO 620 × OIJ 267	-	OIN 028 × OIN 580 OIN 580 × JRO 128 JRO 128 × JRO 878	OIN 028	OIN 217 × OIN 574

Table 4. Additive Main Effect and Multiplicative Interaction (AMMI) analysis of variance for fibre yield and quality traits of 9 parents and their 36 crosses in tossa jute

Characters	Source	Df	SS	% of G-E SS	MS	% G × E Interaction
Fibre yield (q/ha)	Genotypes	44	1.420	10.08	0.032*	
	Environments	4	8.948	63.51	2.237**	
	G × E Interaction	176	3.722	26.42	0.021**	
	PCA I	47	1.446	10.26	0.031*	38.85
	PCA II	45	0.935	6.64	0.021	25.13
	PCA III	43	0.807	5.73	0.019	21.69
	Residuals	41	0.553		0.013	14.33
	Error	440	5.918		0.013	
	Total	224	14.089		0.063	
Fibre tenacity (g/tex)	Genotypes	44	0.955	25.09	0.022**	
	Environments	4	1.168	30.69	0.292**	
	G × E Interaction	176	1.683	44.22	0.010**	
	PCA I	47	0.559	14.69	0.012	33.21
	PCA II	45	0.437	11.48	0.010	25.99
	PCA III	43	0.387	10.17	0.009	22.99
	Residuals	41	0.299		0.007	17.81
	Error	440	0.799		0.002	
	Total	224	3.806		0.019	
Fibre fineness (tex)	Genotypes	44	6.190	46.27	0.141**	
	Environments	4	1.435	10.73	0.359**	
	G × E Interaction	176	5.752	43.00	0.033**	
	PCA I	47	1.942	14.52	0.041	33.76
	PCA II	45	1.547	11.56	0.034	26.89
	PCA III	43	1.364	10.20	0.032	23.71
	Residuals	41	0.899		0.022	15.63
	Error	440	1.273		0.003	
	Total	224	13.377		0.597	

*, ** significant at 5 and 1 per cent levels, respectively

Electronic Journal of Plant Breeding, 8(1): 216-225 (March 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00031.X

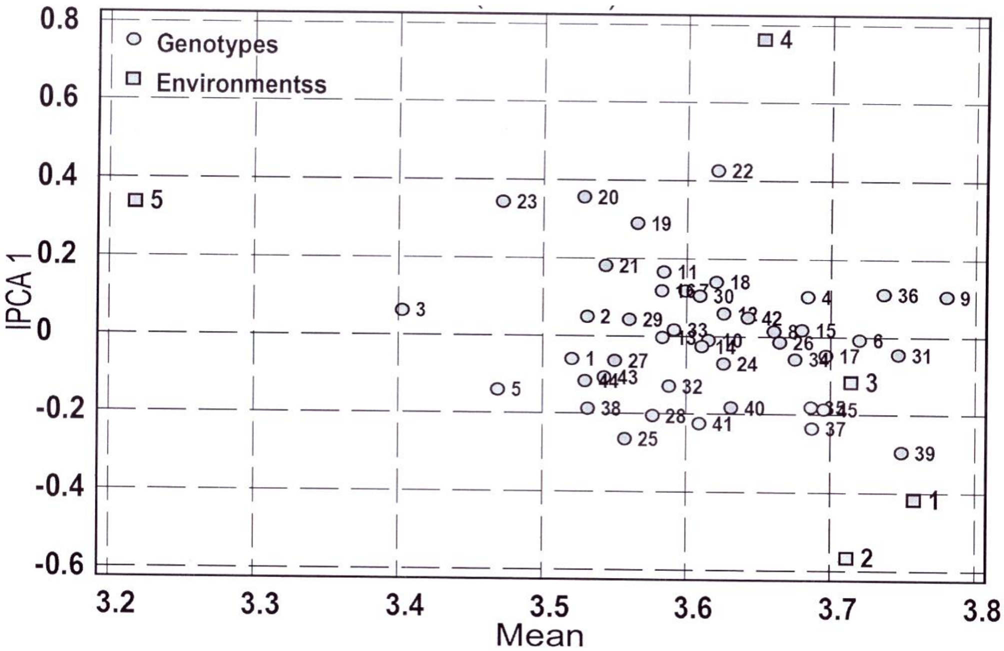

Fig. 1. AMMI 1 biplot of main effects and G × E interaction for fibre yield of 45 tossa jute genotypes in five environments

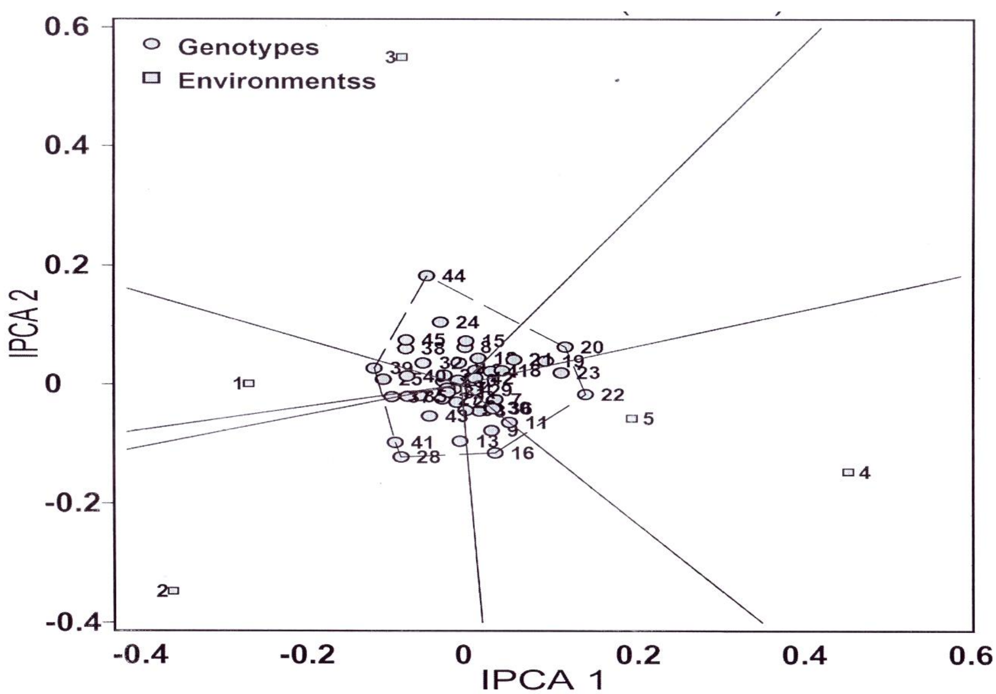

Fig. 2. AMMI 2 biplot of G × E interaction of for fibre yield of 45 tossa jute genotypes in five environments

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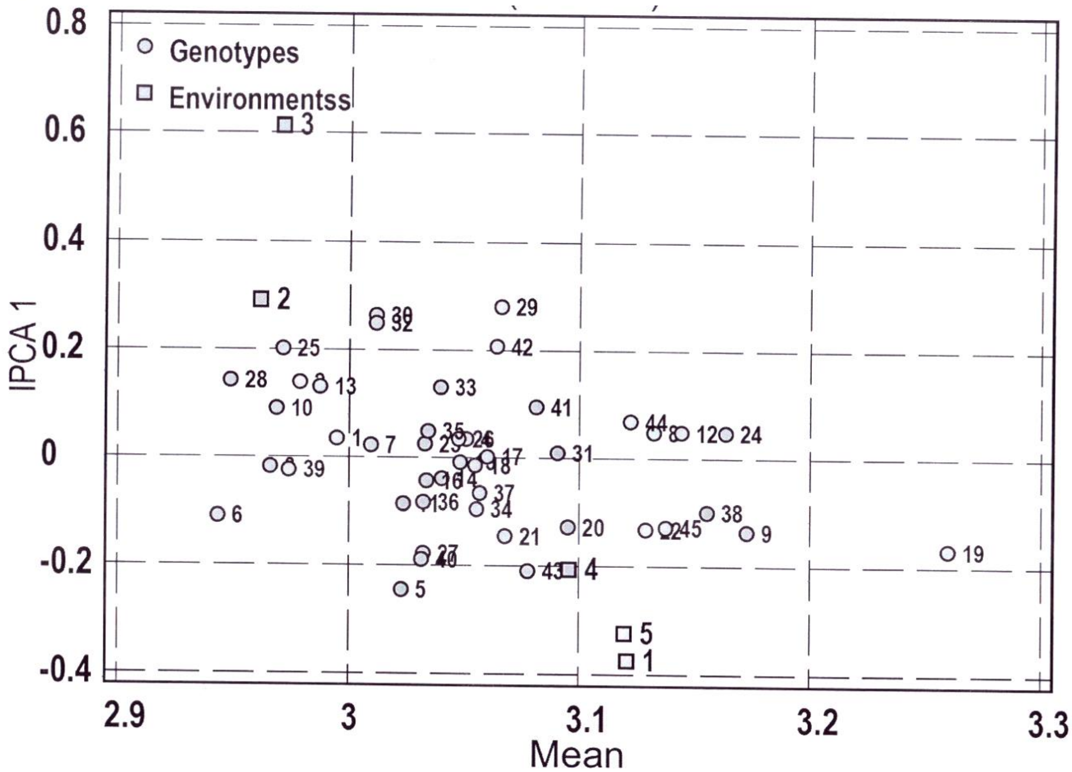

Fig. 3. AMMI 1 biplot of main effects and G × E interaction for fibre tenacity of 45 tossa jute genotypes in five environments

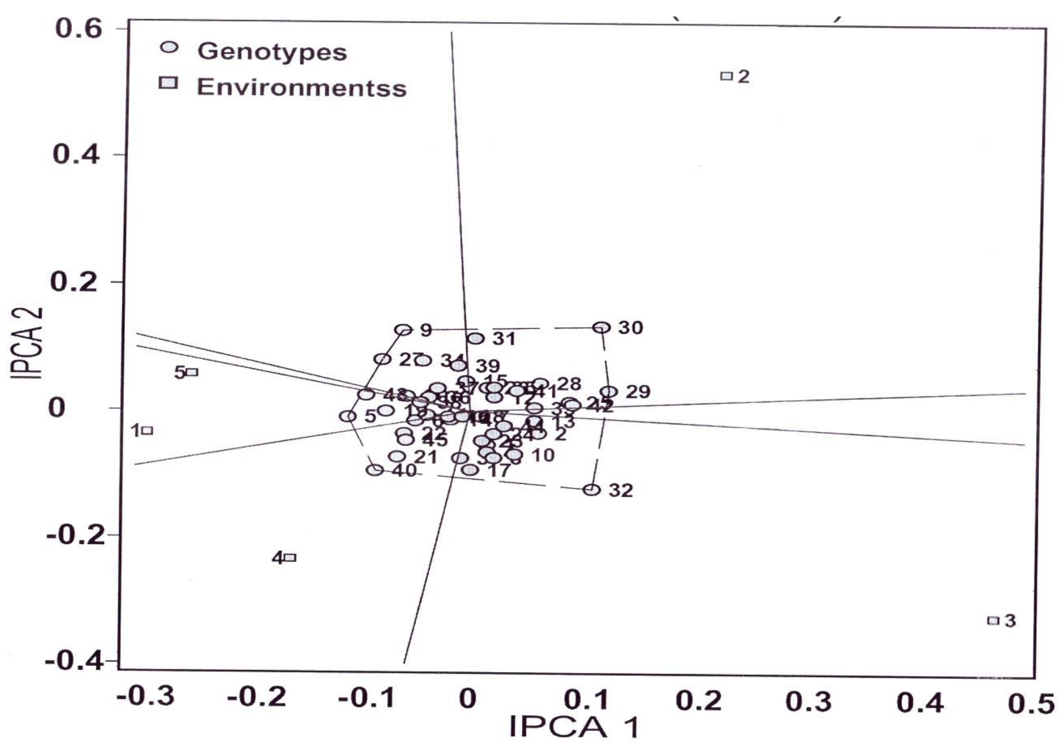

Fig. 4. AMMI 2 biplot of G × E interaction of for fibre tenacity of 45 tossa jute genotypes in five environments

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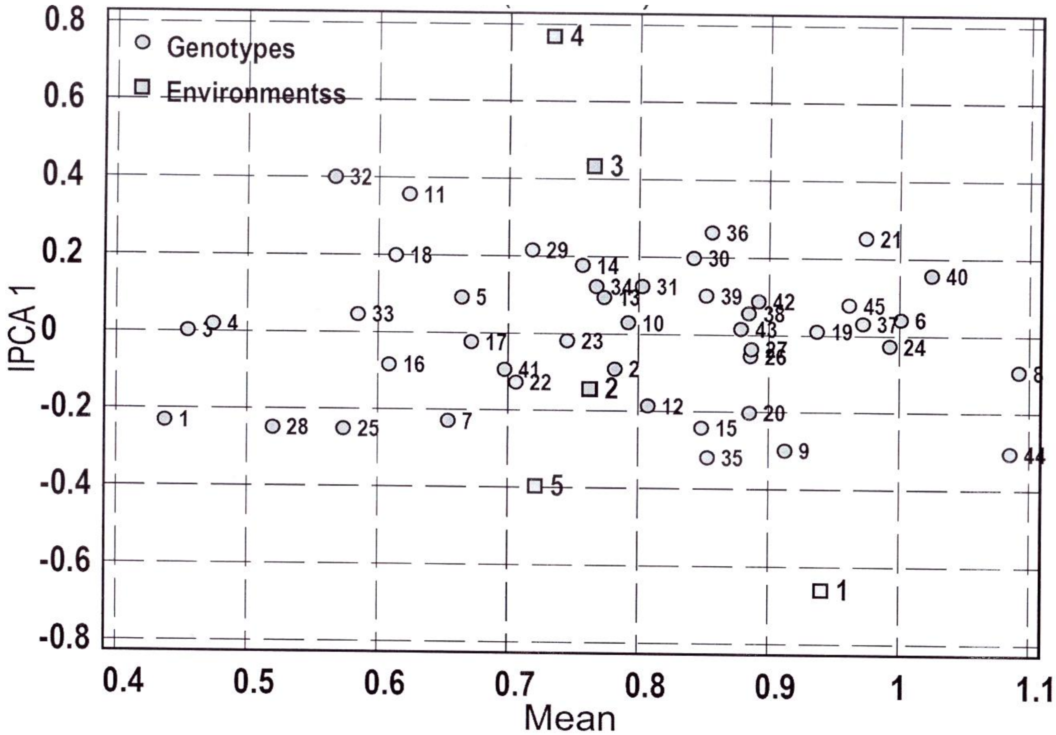

Fig. 5. AMMI 1 biplot of main effects and G × E interaction for fibre fineness of 45 tossa jute genotypes in five environments

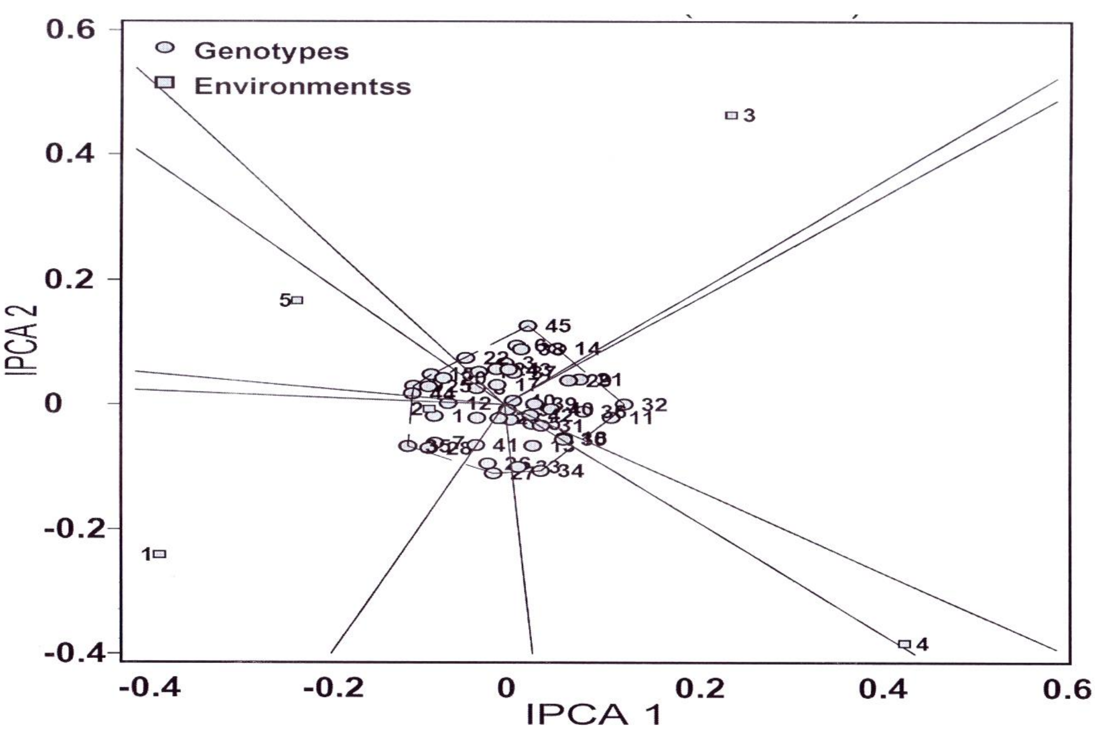

Fig. 6. AMMI 2 biplot of G × E interaction of for fibre fineness of 45 tossa jute genotypes in five environment