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Stability analysis of interspecific cotton hybrids (*Gossypium hirsutum* × *G . barbadense*)

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ABSTRACT

A study was conducted during 2003–06 to assess the yield stability of 74 interspecific cotton hybrids (*Gossypium hirsutum* L. × *G. barbadense* L.) across 3 environments by using the Additive Main effects and Multiplicative Interactions analysis. The Additive Main effects and Multiplicative Interaction analysis of variance indicated that the mean sum of square for seed cotton yield indicated that the genotypes, environments and G × E interaction were significantly different ($P < 0.01$) and it also showed that the environments, genotypes and G × E accounted for 84, 10 and 62% of the treatment sum of squares respectively. The proportion of environmental and G × E interaction variation for seed cotton yield was much larger than the main effects of the genotypes. The genotypes 'G 64,' 'G 58' and 'G 15' showed higher mean seed cotton yield with Principal Component Analysis (PCA) score near to zero indicating higher stability with general adoptability at all environment. The lowest yield was obtained in 'G 3' (820 kg/ha), followed by 'G 14' (954 kg/ ha), 'G 21' (933 kg /ha) and 'G 53' (862 kg/ha).

Key words: AMMI analysis, Biplot, Cotton, Interspecific hybrids, Yield

Cotton (*Gossypium* spp), a predominant natural fibre crop grown as a commercial crop contributes significantly to the Indian economy. It is cultivated widely under different edaphic and environmental conditions. In the years of heavy monsoon or untimely monsoon set in Tamil Nadu, erratic environment prevails which affects the quantitative and qualitative traits of the crop drastically. The major concern of a breeder is to develop stable genotypes that give maximum economic yield/unit area and consistent performance for productivity across environments. One of the important constraints in achieving higher yield is the non-availability of stable interspecific (*G. hirsutum* L.× *G. barbadense* L.) cotton hybrids under varied environments. The success of identifying high-yielding genotypes from yield trials depend on the effectiveness of the statistical tools used to evaluate patterns in the data on the estimated seed cotton yields (Lameie Heravani *et al.* 2005.). Cotton, a sensitive crop to weather fluctuations it shows higher magnitude of genotype × environment interaction (Campbell and Jones 2005.). Identification of suitable cotton genotypes to boost the level of production and productivity across environment is paramount task.

In analysis of interactions, Additive Main effects and Multiplicative Interaction (AMMI) model has been found to be an effective tool (Adalgisa Aranha de Souza *et al.* 2007), since it separates the additive main effects from the interaction, which is analyzed as a multiplicative component using principal component analysis by which interaction patterns can be analyzed. AMMI model computes the principal component scores for genotypes and environments that represent the G × E interaction. Genotypes or environments which appear almost on a vertical line have similar means; those falling on horizontal line have similar interaction patterns. Genotypes or environments with large Interactive Principle Component Analysis (PCA) scores (either + or) have larger interaction while those with values closer to zero have lesser interaction and are considered stable. The present study was carried out to determine the effects of G × E interaction on the yields of new cotton hybrids to identify the most stable and adapted hybrids.

MATERIALS AND METHODS

The experimental material comprised 72 interspecific (*G. hirsutum* L. × *G. barbadense* L.) hybrids with 2 check hybrids, viz. 'Sruthi' and 'TCHB 213.' All the 74 interspecific hybrids were grown in the experimental farm at Regional

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Station, Central Institute for Cotton Research, Coimbatore, during 2003–04 (E_1), 2004–05 (E_2), and 2005–06 (E_3) winter (*rabi*) season to create 3 environments. The trials were conducted in a completely randomized block design with 3 replications in each environment. Each hybrid was grown in a 3 row plot of 4.5 m length and the seed cotton was harvested from each plot in 2 pickings and pooled. The plot yield was extrapolated into seed cotton yield expressed in kg/ha. The data on seed cotton yield (kg/ha) was analyzed for stability according to two-way Additive Main effects and Multiplicative Interaction (AMMI) model. To determine the effects of genotype × environment interaction on yield, the data were analyzed to AMMI analysis carried out by using IRRISTAT (IRRI 2003) version 4.4 computer package. The biplot was drawn by placing the overall mean on the X-axis and the respective score (IPCA) on Y-axis ((Adalgisa Aranha de Souza *et al.*, 2007.)). The basic AMMI model is:

$$Y_{ij} = \mu + g_i + e_j + \Sigma \gamma_k \delta_{ik} Y_{jk} + \Sigma_{ij}$$

where, Y_{ij} is the yield of *i-th* genotype in the *j-th* environment; μ is the grand mean; g_i and e_j are the genotype and environment deviations from the grand mean respectively; γ_k is the eigen value of the principal component analysis (PCA) axis k, Y_{ik} and δ_{jk} are the genotype and environment principal component scores for axis k ; N is the number of principal components in the AMMI model; Σ_{ij} is the residual term. Genotype and environment PCA scores are expressed as unit vector times the square root of γ_k. Genotype PCA score = $\gamma^{0.5}{}_k\ \delta_{ik}$, Environment PCA score = $\gamma^{0.5}\ \delta_{ik}$.

RESULTS AND DISCUSSION

AMMI analysis of variance for seed cotton yield (Table 1) indicated that genotypes, environments and G × E interactions were significantly different ($P < 0.01$) suggesting broad range of diversity existed among genotypes and among environments and the performance of genotypes was different across the environment. Environment accounted for the largest proportion of the sum of square (84.15%), followed by G × E (62.34%) and genotypes (10.48%). It was observed that G × E effects was more important than genotype effects. The Interaction Principle Component Axis (IPCA) was significant ($P < 0.01$) as the AMMI model effectively partitioned to fit adequately with the data. Environmental effects are important factors to understand the plant growth. The experimental results indicated that the proportion of environmental and G × E interaction variation for seed cotton yield was much larger than that due to main effects of genotypes. These results concurred with the findings of Naveed *et al.* (2007) which implied that the proportion of sum of squares due to difference among environments were larger than the main effects of the hybrids. The earlier reports (Kaya *et al.* 2002, Dimitrios Baxebanos *et al.* 2007.) also mentioned that yield was affected by both environment and G × E interaction effects. Among the environments, E_1 and E_3 were found to be the most discriminants as indicated by the longest distance between their respective markers and origin. In general, factors like type of crop, diversity of the germplasm and range of environmental conditions will affect the degree of complexity of the best predictive model (Campbell and Jones 2005).

Table 1 Additive main effects and multiplicative interaction analysis of variance for seed cotton yield of the genotypes across environments

Source of variance	df	S S	M S
Total	540	391882592	697759
Treatments	224	358461765	3148652 **
Genotypes	73	41069572	2905295 **
Environments	2	32978521	40385196 **
G × E	148	24432165	617747 **
IPCA	74	33729580	1642577 **
Residual	83	32576128	1703321 **
Pooled error	316	53602672	147256

**(P=0.01); IPCA, Interaction principal component axis

Yield performance of the genotypes

The yield performance of 74 hybrids in 3 environments is given in Table 2. The mean seed cotton yield of 'G 64' (2 479 kg/ha), 'G 58' (2 309 kg /ha), 'G 19' (2 150 kg/ha), and 'G 65' (2 135 kg/ha) over 3 environments was higher than both the check hybrids 'G 73' ('Sruthi' 1 060 kg/ha) and 'G 74' ('TCHB 213', 1 669 kg/ha). The Interactive Principle Component Analysis scores for genotypes, 'G 64', 'G 58' and 'G 15' were nearer to zero which indicated better stability for seed cotton yield than other hybrids. The remaining stable hybrids ('G 3', 'G 13', 'G 38' and 'G 72') showed below average responsiveness indicating their stability for poor environments. Similar findings have been reported for stability of cotton yield by Tuteja *et al.* (2006). Mean seed cotton yield over environments showed that 'G 64' (2 479 kg/ha) was the best yielding hybrid and 'G 53' (862 kg/ha) was the poor yielder among the hybrids evaluated. The hybrids 'G 74', 'G 40', 'G 16', 'G 51', and 'G 13' which were occupying the right side below the mid point are moderate yielders but they are not stable hybrids. Among these hybrids, 'G 15' is nearer to zero for the IPCA score which shows that it has high stability for seed cotton yield than other hybrids. However the mean performance of the hybrids 'G 38', 'G 62', 'G 72' and 'G 59' were average and they were stable.

Stability and adaptation of the genotypes

The main effects and their scores of the interactions (IPCA) of both hybrids and environments simultaneously are pictorially presented (Figs 1, 2, 3). Genotypes and environments on the same parallel line, relative to the ordinate have similar yields and hybrids on the right side of the

Table 2 Mean seed cotton yield (kg/ha) of 74 interspecific cotton genotypes at 3 locations

Genotype	Environment			Mean
	E_1	E_2	E_3	
'G1'	1 862	1 920	1 760	1 847
'G2'	1 563	1 689	1 670	1 640
'G3'	802	799	861	820
'G4'	1 375	1 502	1 422	1 433
'G5'	1 406	138	1 481	1 008
'G6'	1 385	1 420	1 292	1 365
'G7'	1 427	1 392	1 402	1 407
'G8'	924	855	976	918
'G9'	1 501	1 524	1 384	1 469
'G10'	1 344	1 287	1 400	1 343
'G11'	1 427	1 382	1 360	1 389
'G12'	1 527	1 608	1 385	1 506
'G13'	1 889	1 987	1 395	1 757
'G14'	927	954	982	954
'G15'	1 994	2 803	1 774	2 190
'G16'	1 571	1 655	1 201	1 475
'G17'	1 421	988	1 200	1 203
'G18'	1 300	1 199	1 200	1 233
'G19'	2 188	2 200	2 063	2 150
'G20'	1 418	1 227	1 355	1 333
'G21'	921	994	883	933
'G22'	983	924	1 253	1 053
'G23'	1 119	1 203	996	1 106
'G24'	1 129	1 006	900	1 011
'G25'	975	994	1 002	990
'G26'	1 013	989	1 100	1 034
'G27'	845	1 001	902	916
'G28'	1 127	1 291	1 384	1 267
'G29'	993	1 041	1 318	1 117
'G30'	1 112	999	1 214	1 108
'G31'	1 381	1 206	980	1 189
'G32'	992	1 004	1 019	1 005
'G33'	980	968	874	940
'G34'	1 408	1 301	1 117	1 275
'G35'	988	1 016	1 140	1 048
'G36'	1 320	1 406	1 213	1 313
'G37'	1 027	977	1 200	1 068
'G38'	906	890	811	852
'G39'	1 372	1 501	1 281	1 384
'G40'	923	1 385	1 465	1 257
'G41'	1 581	1 704	1 665	1 650
'G42'	1 175	1 260	987	1 140
'G43'	1 524	1 360	1 166	1 350
'G44'	1 340	1 148	1 380	1 289
'G45'	1 001	1 218	1 260	1 159
'G46'	892	1 250	1 315	1 152
'G47'	1 412	1 286	1 300	1 332
'G48'	1 314	991	880	1 061
'G49'	1 950	878	915	1 247
'G50'	992	1 008	1 240	1 080
'G51'	1 203	996	1 130	1 196
'G52'	1 813	1 425	1 165	1 467
'G53'	886	857	842	862
'G54'	1 340	984	910	1 078
'G55'	1 215	1 086	1 127	1 142
'G56'	1 168	1 064	992	1074
'G57'	1 106	866	1 280	1 084
'G58'	2 258	2 355	2 316	2 309
'G59'	1 001	1 150	887	1 012
'G60'	1 701	1 821	1 665	1 729
'G61'	985	1 022	1 104	1 037
'G62'	845	836	908	863
'G63'	1 618	1 386	1 400	1 468
'G64'	2 478	2 550	2 409	2 479
'G65'	2 080	2 117	1 908	2 135
'G66'	2 062	1 875	1 696	1 861
'G67'	1 861	1 384	1 762	1 669
'G68'	1 506	1 684	1 265	1 485
'G69'	1 108	1 346	1 388	1 280
'G70'	1 222	1 217	1 360	1 266
'G71'	1 216	1 627	1 386	1 409
'G72'	921	792	1 001	905
'Sruthi (C)'	1 119	927	1 135	1 060
'TCHB 213 (C)'	1 600	1 761	1 647	1 669

midpoint of the axis have higher yields than those on the left hand side. Consequently the genotypes 'G 64', 'G 58' 'G 19' and 'G 65' gave higher yields with 'G 64' being the best. In contrast, 'G 53', 'G 21','G 3', 'G 14', 'G 21', and 'G 53' gave below average yield and 'G 53' being the over all poor yielder. Among the 3 environments, E_2 which was on the right hand side of the midpoint of the main effect axis seemed to be favourable environment for seed cotton yield among the hybrids evaluated. However E_3 was considered as moderately favourable environment. Genotypes with Interactive Principle Component Analysis scores nearer to zero (either + or –) had little interaction across environments and *vice-versa.* Four groupings were evident from the biplot; though 'G 72', 'G 38', 'G 62' and 'G 59' were low yielding but moderately stable across environments while 'G 64' and 'G 58' were high yielding and stable, which had negligible interactions with the environments, indicating their broad adaptations and stability across environments (Dimitrios Baxebanos *et al.* 2007.). He pointed out that genotypes exhibiting small interaction with the environments can be considered as more stable and better adapted to the testing environments. The hybrids 'G 3', 'G 14', 'G 21' and 'G 53' had poor seed cotton yield, highly unstable and their adaptation across the environments was also poor.

A biplot is generated using genotype and environmental scores of the first 2 AMMI components (Van Eeuwijk *et*

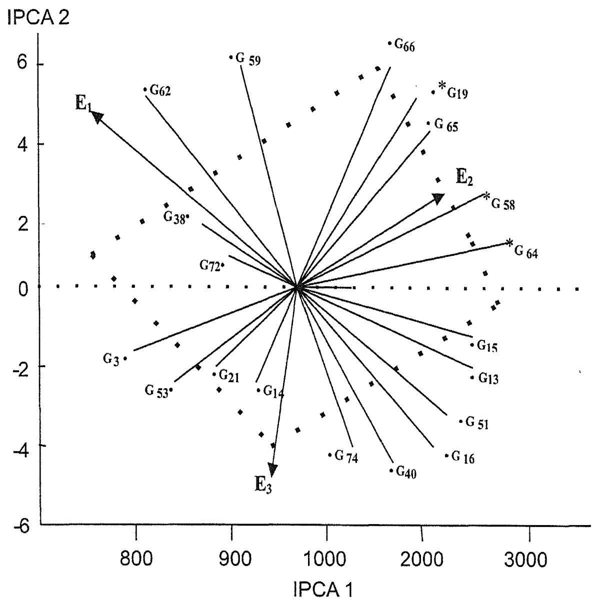

Fig 1 Biplot of 74 genotype and 3 environments for seed cotton yield using genotypic and environmental scores IPCA 1

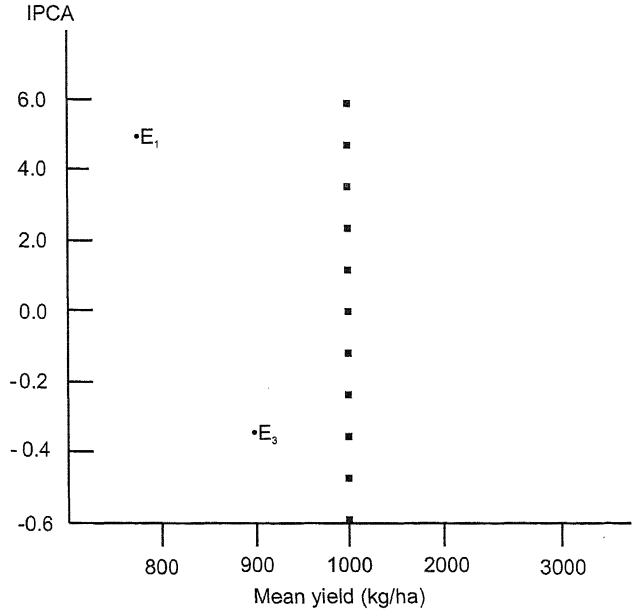

Fig 3 Biplot of interaction principal component axis (IPCA) against mean yield of 3 environments

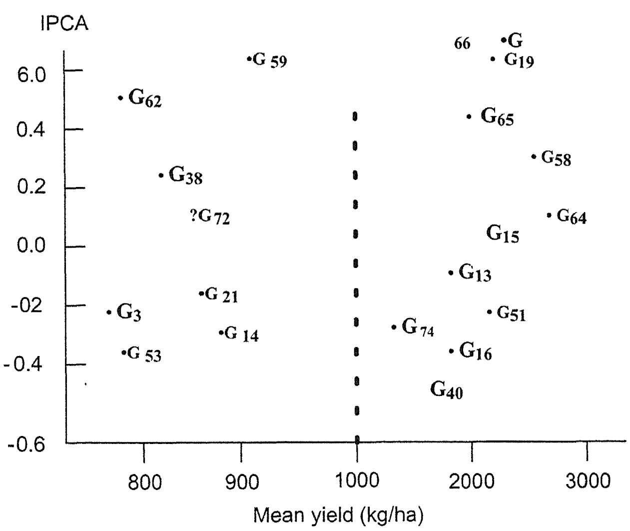

Fig 2 Biplot of interaction principal component axis (IPCA) against mean yield of 74 genotype

*al.*1999). A biplot has four sections depending upon signs of the genotype and environmental scores. For seed cotton yield, four stable hybrids, viz 'G 64', 'G 58', 'G 13' and 'G 15' displayed high mean value and these hybrids can be considered as the most stable hybrids. Similar findings have been reported for stability of cotton yield by Tuteja *et al.* (2006) and Pund and Dev (2006). The hybrids 'G 64' and 'G 58' were the best with respect to environment (E_1) and 'G 38', 'G 59', 'G 62', 'G 72' were the best for E_3 environment, but they had moderate cotton yield. 'G 64' and 'G 58' gave the maximum seed cotton yield (largest PCA scores) but were stable over the environments. In contrast, the non-adaptive genotypes 'G 53', 'G 21' and 'G 14' yielded poorly at all environments as indicated by their small PCA scores (low yielding). The hybrids 'G 3', 'G 13', 'G 15', 'G 16', 'G 40', 'G 51' and 'G 74' were average yielders (PCA scores < 0) but they were unstable. The biplot shows the yield of the main effects of the hybrids (PCA). With respect to the test environments, E_1 was the most discriminating as indicated by the longest distance between its marker and the origin.

The prediction assessment indicated that AMMI with interaction principal component was the best prediction model (Adalgisa Aranha de Souza *et al.* 2007). Thus, the interaction of 74 interspecific hybrids with 3 environments could best be predicted by interaction principal components. The study indicated that although several genotypes were closely related, they responded differently to the varied environments as the proportion of environment variance and the G x E interaction were greater than genotypic variance.

The study indicated that the hybrids 'G 64', 'G 58', 'G 19' and 'G 65' gave more yield than the check hybrids. Among them 'G 64' and 'G 58' were found stable and their consistent performance proved to be suitable for productivity over environments.

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