MODIFIED AMMI METHOD FOR MEASURING PERFORMANCE STABILITY FOR DIFFERENT GENOTYPES OVER DIFFERENT ENVIRONMENTS

S.A. El-Shaarawy
Cotton Research Institute,
Agricultural Research Center
Giza, Egypt

Abstract

The author suggested some modifications to the additive main effect and multiplicative interaction (AMMI) method to increase its accuracy for measuring stability of genotypes. Using the suggested modifications, four stability levels could be defined. The four stability levels are high, above average, average and below average. The genotype with a high level of stability should have both the first interaction principal component axis (IPCA 1) and the second interaction principal component axis (IPCA 2) equal zero. The level of stability for a genotype with IPCA 1 equal to zero is considered to be above average. The genotype considered to having an average level of stability if its IPCA 2 is equal to zero. Any genotype with IPCA1 and IPCA 2 not equal zero considered to having below average level of stability.

The modified AMMI method was applied to thirty Egyptian genotypes (*Gossypium barbadense L.*) grown at five locations. The mean squares for environment (E), genotype (G) and GE interaction were highly significant for all traits. The mean square for IPCA1 was highly significant for all traits. The IPCA 2 mean square was significant for boll weight and highly significant for lint yield. The mean square for IPCA 3 was highly significant for lint yield. Four genotypes (F_5 691/91, F_6 795/91, F_6 744/91 and Giza 75) showed a high level of stability for boll weight. For lint yield, four genotypes (M_5 491/91, F_6 678/91, F_5 720/91 and Giza 81) showed a high level of stability. Nine genotypes (M_5 496/91, M_5 507/91, F_5 689/91, F_5 720/91, F_6 794/91, F_6 744/91, F_6 757/91, F_7 893/91 and F_8 901/91) exhibited a high level of stability for lint percentage.

Introduction

The method outlined by Tai (1971) was applied through the Egyptian cotton breeding program to determine the level of stability for each genotype. Recently, many investigators emphasized the Additive Main effects and Multiplicative Interaction (AMMI) model as a tool to analyze genotype-environment interaction and to define stability for each genotype (Kempton (1984), Gauch (1985, 1988, 1990-a and 1999-b), Gauch and Zobel (1988 and 1989), Zobel *et al* (1988), Crossa (1990), Crossa *et al* (1990 and 1991) and Nachit *et al* (1992)). The AMMI model was applied, for *Gossypium hirsutum*, by Gutierrez, Lopez and El-Zik (1994 and by Cruz-Medina and Hernandez-Jasso (1994). They reported that the IPCA 1 accounted for 45-54.2% of the genotype-environment interaction sum of squares.

The AMMI method as mentioned by those authors didn't use confidence limits to define the area where Interaction Principal Component Axis (IPCA) don't differ significantly from zero. Therefore, the objective of this investigation was to suggest a formula to draw confidence limits for IPCA 1 scores equal zero and for IPCA 2 scores equal zero to define accurately the level of stability for each genotype.

Materials and Methods

The data of this investigation were previously used by El-Shaarawy (1998). Here, thirty cotton genotypes (*Gossypium barbadense*) were grown in a randomized complete block design at five locations in 1993. The five locations were Tanta, Menia El-Kamh, Sers El-lyan, Faraskor and Met Gamr in the Nile Delta of Egypt. The genotypes were five cultivars (Giza 86, Giza 89, Giza 75, Giza 81 and Giza 85) and twenty-five strains. The twenty-five strains were derived from seven crosses. Three traits (boll weight, lint yield and lint percentage) were studied.

A BASIC computer program was written according to the method outlined by Gauch (1990), for AMMI analysis. The data from the five locations were analyzed by using this program. The AMMI model equation is:

$$Y_{ger} = \mu + \alpha_g + \beta_e + \Sigma_n \lambda_n \gamma_{gn} \delta_{en} + \rho_{ge} + \varepsilon_{ger}$$

Where Y_{ger} is the plot value for genotype g in the environment e and replicate r; μ is the grand mean; α_g is the deviation of the genotype g from the grand mean; β_e is the deviation of the environment e from the grand mean; λ_n is the singular value for PCA axis n; γ_{gn} is the genotype eigenvector for axis n; δ_{en} is the environment eigenvector; ρ_{ge} is the residual of the genotype-environment interaction; and ε_{ger} is the error term.

The suggested modification for the AMMI method was to calculate confidence limits for IPCA1 or IPCA2 scores are equal zero. The suggested confidence limits were calculated using the following formula:

$$\pm t_{0.01} ((\Sigma S^2 / (n - 1)) / n)^{1/2}$$

Where S = absolute value of IPCA1 or IPCA2 scores, n = the number of genotypes and $t_{0.01}$ = the tabulated t-value at p = 0.01 and df =n -1.

Plotting the calculated confidence limits to the biplot of IPCA1 and IPCA2 will form three stability zones (Fig. 1).

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The first is zone-A where both IPCA1 and IPCA2 scores do not differ significantly from zero and it contains genotypes with a high level of stability. The second is zone-B where IPCA 1 scores do not differ significantly from zero and it contains genotypes with above average level of stability. The third is zone-C where IPCA 2 scores do not differ significantly from zero and it contains genotypes with average level of stability.

Results and Discussion

The AMMI analysis revealed that mean squares for environment (E), genotype (G) and GE interaction were highly significant for all traits (Table 1). The GE interaction sum of squares was analyzed to three interaction principal component axis (IPCA). The IPCA 1 mean square was highly significant for all traits. The IPCA 2 mean square was significant for boll weight and highly significant for lint yield. The IPCA 3 mean square was highly significant for lint yield. The contribution of IPCA 1 to the GE interaction sum of squares was greater for boll weight and lint percentage and lower for lint yield (Table 2). The IPCA 2 contribution to GE interaction sum square was greater for lint yield. The total contribution of the three interaction principal component axis ranged between 90.16 %, for lint percentage, and 85.77 %, for lint yield.

The biplot of boll weight means (Table 3) and IPCA 1 scores are presented in Figure 2 where the boll weight is presented as the X axis and the coordinates of the first interaction principal component (IPCA 1) as the Y axis. Genotypes with high mean boll weight and IPCA 1 near zero (within the confidence limits for IPCA1) are the better genotypes. Figure 2 showed that three genotypes (F_5 733/91, F_8 899/91, and Giza 75) had high mean boll weight and minimum IPCA 1. The biplot of the IPCA 1 scores and IPCA 2 scores are presented in Figure 3. Four genotypes (F_5 691/91, F_6 795/91, F_6 744/91 and Giza 75) were located in the high stability area. Two strains showed above average level of stability while nine genotypes showed average level of stability for boll weight. For lint yield three strains (F_5 678/91, F_5 691/91 and F_6 744/91) exhibited high mean lint yield and minimum IPCA1 (Fig. 4). The high stability area (Fig. 5) included four genotypes (M_5 491/91, F_5 678/91, F_5 720/91 and Giza 81). Eight genotypes showed an above average level of stability. The average stability area contained eight genotypes. For lint percentage, three genotypes (M_5 507/91, F_6 757/91 and F_7 891/91) showed high lint percentage with minimum IPCA 1 (Fig. 6). Figure 7 showed that nine genotypes (M_5 496/91, M_5 507/91, F_5 689/91, F_5 720/91, F_6 794/91, F_6 744/91, F_6 757/91, F_7 893/91 and F_8 901/91 were located in the high stability area. Six genotypes showed above an average level of stability while ten genotypes showed an average level of stability for lint percentage.

The best strain was F_6 744/91, having high lint yield with an above average level of stability for lint yield and a high level of stability for both boll weight and lint percentage. The next strain was F_5 691/91 which showed high lint yield with above average level of stability for it. Moreover, it showed a high level of stability for boll weight and an average level of stability for lint percentage.

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Table 1. Mean squares for boll weight, lint yield and lint percentage

		Traits		
Sources	df	Boll weight	Lint yield	Lint %
Environment (E)	4	2.2854**	1691.43**	31.06**
Replicate within	25	0.0372	50.82**	2.25
Genotype (G)	29	0.2536**	28.23**	35.09**
G x E	116	0.0507**	8.27**	3.65**
IPCA 1	32	0.0796**	11.41**	5.76**
IPCA 2	30	0.0491*	8.87**	3.49
IPCA 3	28	0.0389	6.86**	3.30
Residual	26	0.0297	5.26	1.60
Error	725	0.0300	3.95	2.56

*, ** Significant at p= 0.05 and p = 0.01, respectively.

Table 2. Percentage contribution of IPCA components to genotype-environment interaction sum square.

	Traits		
Sources	Boll weight	Lint yield	Lint %
IPCA 1	43.30	38.04	43.58
IPCA 2	25.04	27.72	24.76
IPCA 3	18.52	20.01	21.82
Total	86.86	85.77	90.16
Residual	13.14	14.23	9.84

Table 3. Mean performances of thirty genotypes over five environments.

	Traits		
Genotypes	Boll weight (g)	Lint yield (C/F)	Lint %
1 - M_5 491/91	3.00	10.82 +++	38.12 +
2 - " 496/91	2.92	10.64 ++	38.91 +++
3 - " 507/91	3.02	11.95	40.73 +++
4 - F_5 678/91	3.15	12.34 +++	40.29 +
5 - " 689/91	3.10	12.84 +	40.02 +++
6 - " 691/91	3.06 +++	12.06 ++	40.21 +
7 - " 711/91	3.04	11.19 +	38.18
8 - " 720/91	3.14	10.09 +++	39.59 +++
9 - " 733/91	3.23 ++	11.56	38.09 ++
10-" 741/91	3.19	11.35 ++	38.09 +
11-F_6 788/91	3.05	10.21	40.23
12-" 794/91	3.03 +	10.52 ++	38.97 +++
13-" 795/91	3.03 +++	9.91	38.08 ++
14-" 744/91	3.10 +++	12.58 ++	39.07 +++
15-" 749/91	3.05	11.76 +	39.94
16-" 756/91	3.06 +	10.36 +	41.56 +
17-" 757/91	3.08	10.61 ++	40.89 +++
18-F_7 873/91	3.32	11.38 ++	39.32
19-" 891/91	3.27 +	10.36	40.87 ++
20-" 893/91	3.25	10.42 +	41.15 +++
21-" 897/91	3.25 +	11.11	40.32
22-F_8 898/91	3.16 +	13.35 +	39.54 +
23-" 899/91	3.16 ++	12.47	38.67 ++
24-" 901/91	3.11	12.62	38.41 +++
25-" 905/91	3.10 +	12.15 +	38.13 +
26- Giza 86	3.08 +	11.70	39.03 +
27- Giza 89	2.99 +	12.75 +	38.23
28- Giza 75	3.17 +++	11.39 ++	38.17 ++
29- Giza 81	3.11 +	10.14 +++	38.28 ++
30- Giza 85	3.08	12.21	38.27 +
Mean	3.11	11.43	39.34
L.S.D. (p=0.01)	0.11	1.32	1.08

+++ High level of stability.

++ above average level of stability.

+ average level of stability.

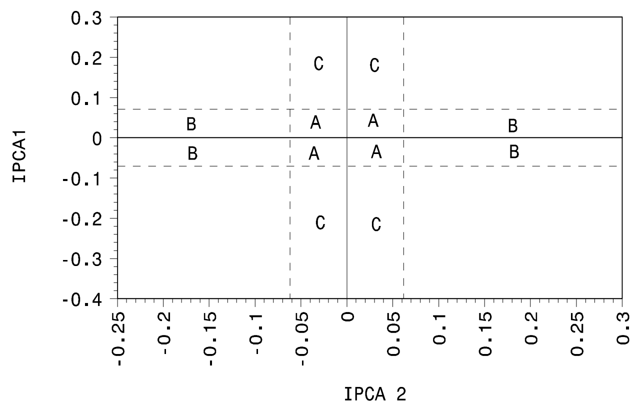

Figure 1. The zones of stability levels (A) high level, (B) above average level and (C) average level of stability.

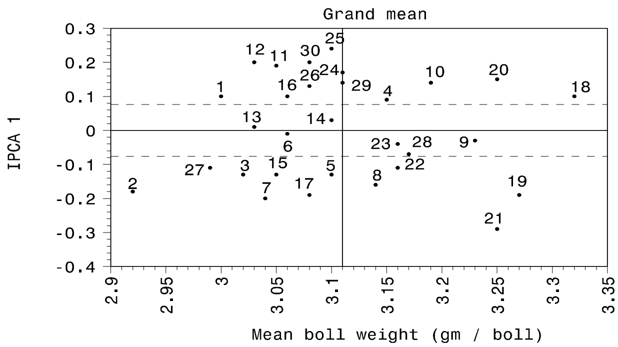

Figure 2. Biplot of boll weight mean and IPCA 1 scores for thirty genotypes.

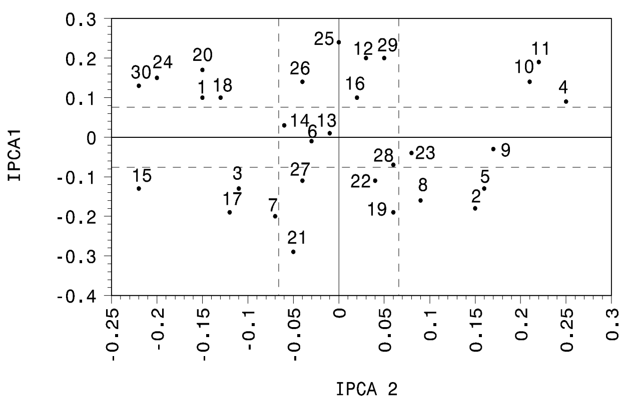

Figure 3. Biplot of IPCA 1 and IPCA 2 scores for boll weight of thirty genotypes.

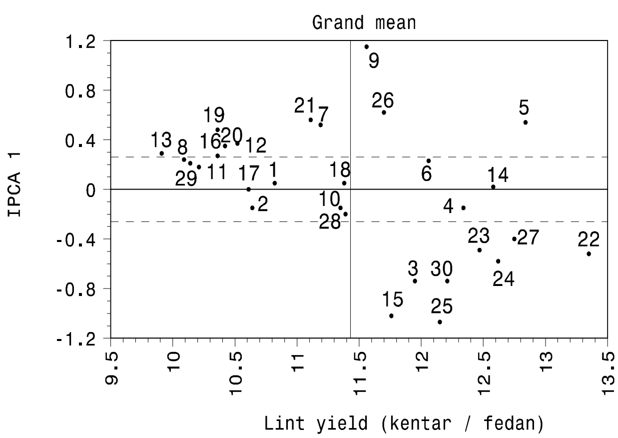

Figure 4. Biplot of lint yield mean and IPCA 1 scores for thirty genotypes.

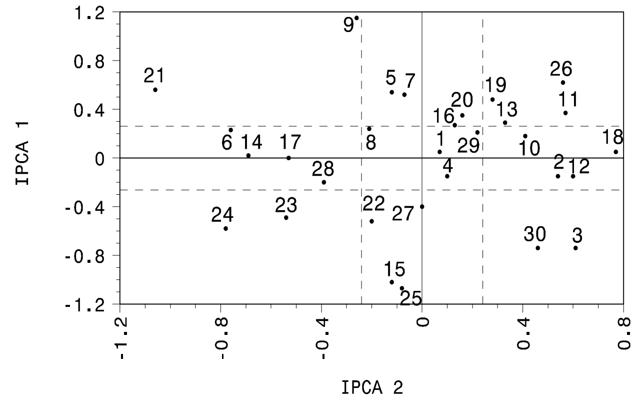

Figure 5. Biplot of IPCA 1 and IPCA 2 scores for lint yield of thirty genotypes.

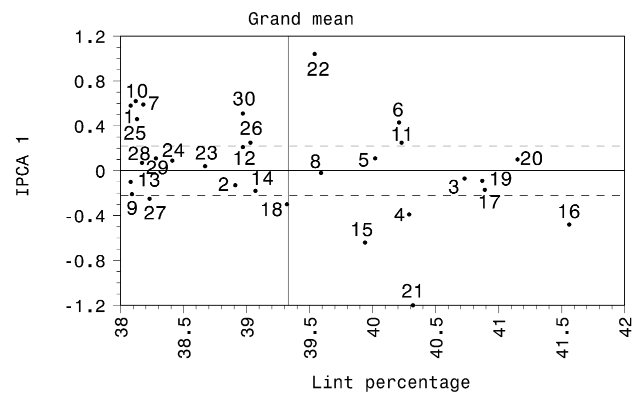

Figure 6. Biplot of lint percentage mean and IPCA 1 scores for thirty genotypes.

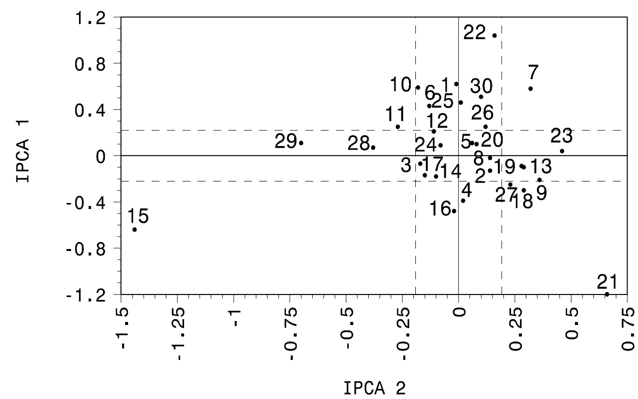

Figure 7. Biplot of IPCA 1 and IPCA 2 scores for lint percentage of thirty genotypes