Korean J. Crop Sci. 48(2): 65~67(2003)

Genotype-by-Environment Interaction in Yield of Sesame

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ABSTRACT: This study was conducted to analyze the effects of genotypes, environments and interaction of G×E on yields of sesame grown in seven different environments by AMMI analysis. Environments accounted for the largest (91%) proportion of the sums of squares, followed by G×E (8%) and genotypes (1%) Therefore, G×E effects are theoretically eight times as important as G effects. G2 (Yanghukkae) has the largest IPCA1 scores indicating higher G×E interaction. G3 (Suwon 171) was near zero score of IPCA1 suggesting higher stability than others in yield component. Most of environments except for Iksan area shows different G×E effects by years, which means Iksan is optimal area for multi-environmental adaptation evaluation in sesame breeding programs. According to this experiment, it is concluded that maximization of grain yield through environments can be achieved by specific genotypes in specific environments.

Keywords : Sesame, G×E, AMMI, Genotype effects, Environmental effect

Sesame (*Sesamum indicum*) was originated from tropical areas, so it has been very sensitive to the changes of cultivation environments in the temperate region such as Korean peninsula. It has been known that annual grain yield of sesame in Korea varies according to the cultivation environments of both locations and years. Therefore, the most important target of the sesame breeding program in Korea should be to develope new varieties which have higher stability to the cultivation environments and diseases. Up to date, most of statistical data have been analyzed by the classical analysis of variance which has not been effective for detailed study of underlying patterns of interactions. No attempts have been made to analyze interactions between genotypes and environment (G×E) on yields of sesame.

For more detailed analysis of the interactions, the additive main effect and multiplicative interaction (AMMI) model has been found to be an effective tool (Allard *et al.*, 1964). AMMI is especially effective where the assumption of linearity of the response of genotype to a change in the environment is not fulfilled (Zobel *et al.*, 1988; Yan, 1998) and which is required in stability analysis techniques (Eberhart and Russell, 1966). The AMMI model dose not require this assumption. It usually separates the interaction part of the multiplicative components into the additive main effects by principal component analysis.

The objective of this study is to quantify the G×E interaction effects on yield in terms of different sesame cultivation environments in Korea by which it is possible to evaluate new sesame varieties with higher stability and select optimal environments for sesame adaptation evaluation.

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<Received November 21, 2002>

MATERIALS AND METHODS

Plant materials and environments

This experiment was conducted at Suwon, Iksan, Taegu, Jinju, and Naju areas from 1999 to 2001. Two varieties and five selected lines were used: Yangbaekkae, Yanghukkae, Suwon 171, Suwon 172, Suwon 173, Iksan 16, and Iksan 17. The size of experimental plot was about 12 . Seeds were sown in the holes of black polyethylene film mulch at 30×10 cm spacing and thinned to grow one plant per hole. Fertilizer (N-P_2O_5-K_2O=8-4-9) was applied as the basal fertilizer. Soil characteristics of each location were analyzed in the three years. pH was ranged from 5.5 to 7.1, O.M.(%) 0.30~0.87, and Av. P_2O_5 20.3~130.0. Among the exchangeable cations, K was ranged from 0.14 to 1.86, Ca 2.70~5.90, and Mg 0.87~3.23. C.E.C (mg/100 g) was ranged from 4.73 to 10.90.

Methods of statistical analysis

The AMMI model is $Y_{ij} = \mu + g_i + e_j + \sum_{1}^{N} \lambda_k \gamma_{ik} \delta_{jk} + \varepsilon_{ij}$

Table 1. Average yield and growth characteristics of seven genotypes in the fifteen environments.

No.	Variety & line	Flowering date	Maturity date	Mean yields (kg/10a)
1	Yangbaekkae	July 24	September 4	87
2	Yanghukkae	July 24	September 5	84
3	Suwon 171	July 25	September 5	91
4	Suwon 172	July 26	September 6	90
5	Suwon 173	July 24	September 5	86
6	Iksan 16	July 27	September 7	81
7	Iksan 17	July 26	September 6	88

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 deviations of genotype and environment from the grand mean, respectively. λ_k is the eigenvalue of the principal component analysis (PCA) for axis *k*; γ_{ik} and δ_{jk} are the genotype and environment principal components scores for axis *k; N* is the number of principal components in the AMMI model; ε_{ij} is the residual term. Genotype and environment PCA scores are expressed as unit vector times the square root of

λ_k (genotype PCA score=$\lambda_k^{0.5}\delta_{ik}^{0.5}$, environment PCA score=$\lambda_k^{0.5}\delta_{ik}^{0.5}$, *(Zobel et al.,* 1988)).

RESULTS AND DISCUSSION

Analysis of geneotypes and environments for yield

The ANOVA of grain yield indicate that genotype, environment, and the interaction of G×E are highly significant (Table 2). Environments account for the largest (91%) proportion in the value of sums of squares, followed by G×E (8%), and genotypes (1%). Therefore, G×E effect is theoretically eight times as important as G effect. This means that about 9% of variation is related to the identification of highest yielding lines at different environments according to G and G x E effects proportion. The environment effect is an important factor to understand physiological state of plant growth.

The AMMI model partitions G×E into successively specific patterns. Partitioning of G×E indicates that AMMI-4 model describes the G×E patterns for yield by the first five interaction principal component analysis(IPCA) scores using Gollb's *F*-test (Table 2). Of the total 9.0% variation is due to genotypes and interaction effects, and 7.4% is due to genotype which is explained by line main effect and two largest IPCAs. Remains are error mean squares x interaction degrees of freedom.

Table 2. Additive main effects and multiplicative interaction analysis of variance for grain yield including four IPCA axes.

Source of variation	df	Sum of Squares	SS%	Mean Squares	*F*-test
Total	314	487502.57	100		
Treatment	106	466514.04	96	4401.08	**
Replications	2	1102.80	0.2	551.40	
Genotype	6	3867.24	0.8	644.54	**
Environment	14	423504.48	90.8	30250.32	**
G×E	84	38039.52	8.2	452.85	**
IPCA1	19	26056.22	68.5	1371.38	**
IPCA2	17	4784.22	12.6	281.42	**
IPCA3	15	3766.69	9.9	251.11	**
IPCA4	13	1976.15	5.2	152.01	*
Residual	20	1456.24	3.8	72.81	
Error	208	20988.53	4	100.91	

**, *: Significant at 0.05 and 0.01 probability levels.

Biplot of interaction principal components between genotypes and environments

The biplot of mean grain yield for IPCA1 shows different reaction according to G×E, genotypes and environments (Fig. 1). The biplot accounts for 69% of the variation in total treatment sums of squares (Table 2). The main effects and each score are shown in the graph and used to predict yield of genotypes in each environment.

Higher IPCA scores both positive and negative attribute to higher G×E.

G2 (Yanghukkae) has the largest IPCA1 scores which indicates higher G×E interaction. G3 (Suwon 171) is near to zero score of IPCA1 by which Suwon 171 has higher stability than others in yield component. Otherwise, Yanghukkae and Suwon 173 have higher positive IPCA1 scores,

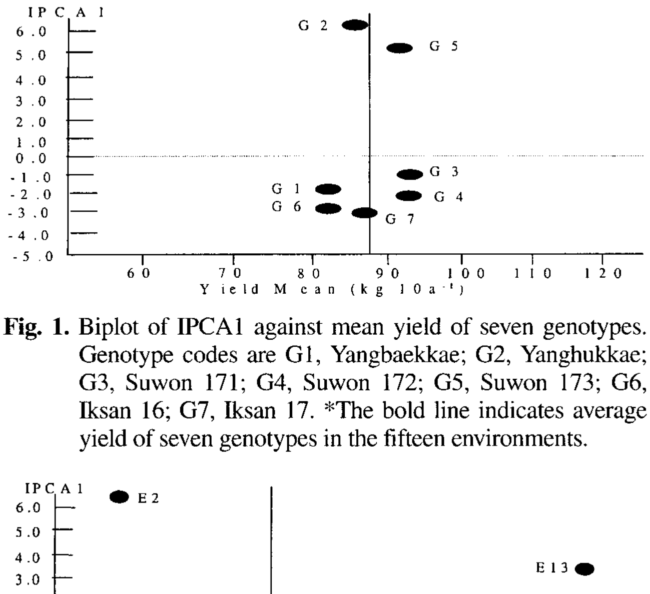

Fig. 1. Biplot of IPCA1 against mean yield of seven genotypes. Genotype codes are G1, Yangbaekkae; G2, Yanghukkae; G3, Suwon 171; G4, Suwon 172; G5, Suwon 173; G6, Iksan 16; G7, Iksan 17. *The bold line indicates average yield of seven genotypes in the fifteen environments.

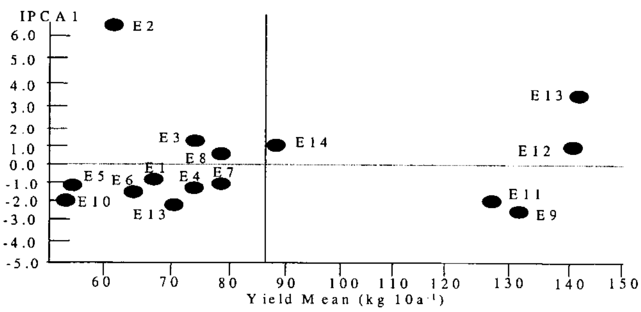

Fig. 2. Biplot of IPCA1 against mean yield of 15 environments. Environment codes are E1, Suwon (1999); E2, Suwon (2000); E3, Suwon (2001); E4, Iksan (1999); E5, Iksan (2000); E6, Iksan (2001); E7, Daegu (1999); E8, Daegu (2000); E9, Daegu (2001); E10, Jinju (1999); E11, Jinju (2000); E12, Jinju (2001); E13, Naju (1999); E14, Naju (2000); E15, Naju (2001). *Bold line means average yields of the fifteen environments.

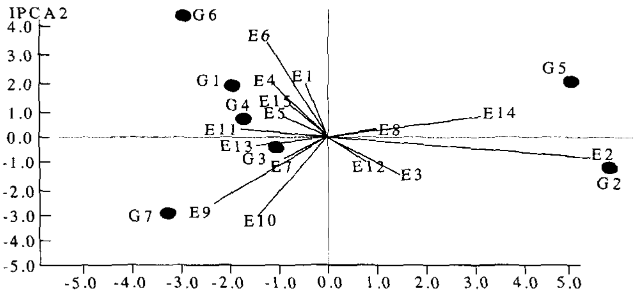

Fig. 3. Biplot of IPCA1 against IPCA2 for yield of seven genotypes (circles) in the fifteen environments (lines).

indicating that the two genotypes have similar yield response against IPCA1 scores.

Response of mean yield of environments at the biplot distribution is more wide spread than those of genotypes (Fig. 2). E2 (Suwon, 2000) and E9 (Daegu, 2001) show high scores which attribute to high G × E interaction.

The biplot of Fig. 3 with IPCA1 against IPCA2 shows relative magnitude and G × E direction according to the interaction effects of genotypes and environments. Generally, genotypes and environments with smaller G × E effects are located at the center of both axes. For example, G3 (Suwon 171) and G4 (Suwon 172) show relatively smaller G × E effects rather than G2 (Yanghukkae) and G7 (Iksan 17). Genotypes and environments marking same or opposite horizontal/vertical direction mean to have same or opposite G × E patterns. According to the biplot analysis, G1 (Yangbaekkae), G4 (Suwon 172) and G6 (Iksan 16) show to have similar G × E interaction patterns rather than G2 (Yanghukkae) and G5 (Suwon 173). E8 (Daegu, 2000) and E14 (Naju, 2000) also have similar interaction patterns rather than E9 (Daegu, 2001) and E10 (Jinju, 1999). E1, E2 and E3 show the different directions on the plot suggesting relatively different G × E effects or magnitudes according to the years. But, E4, E5 and E6 shows the same directions through the years suggesting similar G × E effects or magnitudes.

According to the additive main effect and multiplicative interaction analysis of variance for grain yields which is partitioned into 4 IPCA effects, IPCA1 and IPCA2 sufficiently accounts for more than 80% of G × E variation, and G × E effect is to give eight times greater variation factor than G effect. Therefore, we can conclude G × E interaction is a main factor for the multi-environmental adaptation evaluation of sesame breeding programs.

REFERENCES

Allard, R. W. and A. D. Bradshaw. 1964. Implications of genotype-environment interactions in applied plant breeding. Crop Sci. 4 : 503-507.

Eberhart, S. A. and W. A. Russell. 1966. Stability parameters for comparing varieties. Crop Sci. 6 : 40-46.

Zobel R. W., M. J. Wright, and H. G. Gauch 1988. Statistical analysis of a yield trial. Agron. J. 80 : 388-393.

Yan, W. and L. A. Hunt. 1998. Genotype by environment interaction and crop yield. Plant Breed. Rev. 16 : 135-178.