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Genotype by Environment Interaction for Grain Yield of Salt Tolerance Rice Genotypes in Coastal Saline Area

Interaksi Genotipe x Lingkungan terhadap Hasil Galur Padi Toleran Salinitas di Kawasan Pesisir

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ABSTRAK

Uji multilingkungan dapat mengungkap penampilan dan adaptasi galur-galur generasi lanjut untuk lingkungan spesifik maupun lingkungan luas. Penelitian ini bertujuan untuk menganalisis pola G x E (genotipe x lingkungan) sifat hasil gabah 67 genotipe padi dengan model analisis AMMI (Additive Main Effect and Mulitplicative Interaction) menggunakan data penelitian observasi daya hasil galur-galur padi pada tiga lingkungan tumbuh lahan salin, yaitu Eretan Indramayu, pesisir pantai Narmada Mataram, dan kondisi normal Mataram, Nusa Tenggara Barat. Di tiap lokasi, percobaan ditata dalam rancangan acak kelompok dengan tiga ulangan. Ukuran petak percobaan 5 m2 dan jarak tanam 20 cm x 20 cm2. Kultur teknis mengikuti rekomendasi teknologi setempat. Hasil penelitian menunjukkan terdapat interaksi genotipe dan lingkungan (G x E) yang mempengaruhi penampilan hasil tanaman di setiap lokasi percobaan. Galur G62 (IR 76397-2B-6-1-1-1-1), G64 (IR 76397-2B-6-1-1-1-1), G3 (IR58427-5B-15), G61 (IR 76393-2B-7-1-1-3-1), G19 (IR73055-8-1-1-3-1), G26 (IR 77674-3B-8-2-2-14-1-AJY5), G38 (IR 77674-3B-8-2-2-14-2-AJY4,), G35 (IR77674-3B-8-1-3-13-2-AJY2), G44 (IR68144-2B-2-2-3-3), dan G53 (IR 72593-B-18-2-2-2) memiliki hasil lebih tinggi dari rata-rata hasil di semua lokasi dan pengaruh G x E kecil atau bersifat stabil dibandingkan dengan varietas cek Siak Raya dan Dendang. Galur G23 (IR77674-B-20-1-2-1-3-6-4-AJY1,), G25 (IR77674-3B-8-2-2-12-5-AJY2), G24 (IR 77674-3B-8-2-2-8-3-AJY4,), G18 (IR72049-B-R-22-3-1-1) memiliki hasil tinggi dan berindikasi adaptif di daerah Eretan. Genotype yang hasilnya stabil dan menunjukkan adaptasi yang luas layak sebagai materi untuk pengujian daya hasil pada musim berikutnya.

Kata kunci: *Padi, hasil gabah, toleran salinitas, genotipe x lingkungan.*

ABSTRACT

Multi-environment experiments could reveal the performance and adaptation of the advanced breeding lines for a specific or general environments. The objective of the present investigation was to analyze the pattern of Genotype x Environment (G x E) interaction for grain yield of 67 genotypes by Additive Main effects and Multiplicative Interaction (AMMI) model using the data generated from observational yield trial in three different coastal rice environment in Indonesia including one site in coastal location of Eretan, Indramayu (West Java), and two sites in the coastal area of Mataram, West Nusatenggara during the dry season of 2009. In each location, the experiment was arranged in a randomized complete block design with three replications, 5 m^2 plot size, and 20 cm x 20 cm of plant space. Standard management practices for the rice irrigation field were followed for all trials. The results showed the genotype x environment (G x E) interaction influenced the relative yield ranking of the genotypes across the environments. Genotype 62 (IR76397-2B-6-1-1-1-1), G64 (IR 76397-2B-6-1-1-1-1), G3 (IR58427-5B-15), G61 (IR76393-2B-7-1-1-3-1), G19 (IR73055-8-1-1-3-1), G26 (IR 77674-3B-8-2-2-14-1-AJY5), G38 (IR77674-3B-8-2-2-14-2-AJY4), G35 (IR77674-3B-8-1-3-13-2-AJY2), G44 (IR68144-2B-2-2-3-3), and G53 (IR72593-B-18-2-2-2) produced higher yield compared to the overall mean, and showed low G x E interaction effect or high adaptability compared to check variety Siak Raya and Dendang. G23 (IR77674-B-20-1-2-1-3-6-4-AJY1), G25 (IR 77674-3B-8-2-2-12-5-AJY2), G24 (IR77674-3B-8-2-2-8-3-AJY4), G18 (IR72049-B-R-22-3-1-1), produced high yield and indicated suitable for Eretan environment. Both the stable genotypes and the specific adaptation genotypes with the highest average yield compared to the checks will be further evaluated in yield trials in the following season.

Keywords: Rice, grain yield, salt tolerance, genotype by environment.

INTRODUCTION

Rice is the most important staple food crop for the Indonesian population, provides the main calorie for approximately 271.066 million people. The islands of Java, Sumatera, Sulawesi, Nusa Tenggara, and Bali, are major rice-producing areas, where Java contributes more than 50% of rice production in Indonesia (BPS 2019).

Rice is widely grown in coastal plain areas, where saline seawater frequently inundated during the high tidal periods (Mori and Kinoshita 1987). Soil salinity is a problem on rice production worldwide, the second most widespread soil problem in the rice-growing countries after drought (Gregorio 1997). Sabouri and Sabouri (2008) reported the existence of large variability for salinity tolerance among varieties within species of rice.

At the Indonesian Centre for Rice Research, the development of high yielding rice variety tolerant to salt stress and adapted to the swampy area was carried out especially for saline paddy field in the tidal swampy area of Sumatera and Kalimantan. There are 0.44 million ha of tidal swampy land mainly in Sumatera and Kalimantan islands which are potentially suitable for as rice paddy field (Sudana 2005). Global climate change threatens rice production in the coastal area because of seawater intrusion. In the coastal area of Java, Bali, and Nusa Tenggara, rice is widely grown both on rainfed and irrigated conditions. The salt-affected soil in the north coastal area of Java has been very crucial where about 42.8% (3,32 million ha) of irrigated paddy fields are located (Las 2007). It was reported that total of about 3,005 ha of paddy fields located in Sumbawa (2,016 ha), Bima (535 ha), and Central of Lombok (289 ha) were inundated by salt (Agriculture Bureau of West Nusa Tenggara 2008).

Some rice varieties adaptive to tidal swampy area such as Dendang and Lambur, were reported as moderately tolerant to salinity (Suprihatno *et al.* 2010). It is important to develop variety with high salinity tolerance to anticipate the effect of global climate change. To increase the genetic variability of the breeding materials tolerant to salinity for yield testing, Indonesian Centre for Rice Research had introduced advanced breeding lines through INGER (International Network for Germplasm Evaluation and Utilization of Rice) program coordinated by IRRI. Presently, we evaluated their tolerance to salinity, studied the potential yield and their adaptability and stability across environments in Indonesia.

Genetic environment (G x E) interaction was used to measure varietal stability and suitability for cultivation across ecological zones. The analysis G x E focused on the identification of stable genotypes. The Additive Main Effects and Multiplicative Interaction (AMMI) model had been found more useful recently, since it in-corporated both the classical additive main effects model for G x E interaction and the multiplicative components into an integrated least square analysis and thus becomes more effective in the selecting the stable genotypes (Crossa *et al.* 1991). This study was aimed to elucidate the pattern of responses among genotypes and to select stable rice genotypes on saline soil and normal environment using AMMI analysis.

MATERIAL AND METHOD

Sixty-seven advanced rice breeding lines introduced from IRRI and two check varieties (Siak Raya and Dendang) were evaluated in three sites of coastal rice environments namely on the coastal of Eretan, Indramayu, West Java, and on two sites of coastal area in Narmada, Mataram, West Nusa Tenggara, during the dry season of 2009. The two sites in Narmada represented different salinity level conditions, namely, on normal and on soil affected saline condition. The materials to be tested were salinity tolerance rice lines from IRSSTN (International Rice Soil Stress Tolerance Nursery) program, arranged in RCBD (Randomized Complete Block Design) with three replications. Plot size was 5 m^2, plant spacing was 20 cm x 20 cm. Standard management practices for rice on the irrigated field were adopted for all trials.

Grain yield was measured at14% of grain moisture content of the plot. AMMI (Additive main effect and Multiplicative Interaction) analysis was performed to reveal the responses of genotype yields in different environments. Single analysis and combined analyses of variance were computed using IRRISTAT 7.2 version, and AMMI analysis using PB tool 2013.

The AMMI model is expressed mathematically by:

$$Y_{ij} = \mu + g_i + e_j + \sum_{n=1}^{N} \lambda_k \gamma_{ik} \alpha_{jk} + \rho_{ij} + \varepsilon_{ij}$$

Y_{ij} = is the yield response of genotype i (i=1, 2, .., I) in environment j (j=1, 2,..., J);

μ = is the general mean;

g_i = is the main effect associated to the i-th genotype

e_j = is the main effect associated to the j-th environment;

n = is the number of principal axes (principal components) necessary to describe the "pattern" of the interaction between the i-th genotype with the j-th environment;

λ_k = is the singular value of the k-th principal interaction axis;

γ_{ik} = is the i-th element of the singular column vector associated to axis k;

α_{jk} = is the j-t^{h} element of the singular row vector associated to axis k

ρ_{ij} = is the AMMI residue (interaction "noise"); and

ε_{ij} = is the pooled error term

To rank genotypes in terms of stability, AMMI's stability value (ASV) was calculated using the formula proposed by Purchase *et al.* (2000):

$$ASV = \sqrt{\frac{SSIPCA1}{SSIPCA2}(GPCA1)^2 + (GPCA2)^2}$$

ASV = the distance from zero in a two-dimensional scattergram of IPCA 1 (Interaction Principal Components Analysis) scores against IPCA 2 scores; SSIpca1/SSIpca2 = the weight given to the PCA1 value by dividing the PCA1 sum of squares by the PCA2 sum of squares; GPCA1 score = the PCA1 score for that specific genotype, and GPCA2 = the PCA2 score for that specific genotype.

RESULTS AND DISCUSSION

The degree of soil salinity as indicated by electrical conductivity of soil taken during transplanting time showed that Eretan environment had higher salt stress compared that of Mataram. One site in Mataram was supposed to be salinity stress condition, but during the vegetative stage, the salinity level of this place had decreased due to enough fresh water irrigation. Base on the value of electrical conductivity (ECse). The soil salinity of the two fields the soil in Mataram could be categorized as medium and normal, while the soil in Eretan, the salinity level was high.

The soil texture and pH value of soil in Eretan was more of clay, with pH value near neutral, in Mataram more sandy with pH value was more alkaline, and other site with the normal soil condition was more sandy (Table 1).

Barlett's test indicated homogenous error variance for the grain yield in each of three environments an allowed to proceed further for pooled analysis across environments (data not shown). Anova across environments detected significant variation among genotypes and for the G X E. The analysis of variance of AMMI (Table 2) showed that the mean sum of squares due to genotypes, environments, and genotype x environment interaction was significant, indicating a broad range of diversity existed among genotypes. The presence of GE interaction was an indication of differential yield ranking of cultivars across environments (Samonte *et al.* 2005).

In this study, the genotype with the highest grain yield was different among the environments. Most genotypes produced less grain yield in Eretan compared to those in the two other environments (Figure 1). The mean yield in Eretan, in normal soil Mataram and in coastal Mataram environment was 4.67 t/ha, 6.53 and 8.69 t/ha, respectively. In Eretan, Genotype (G) 18(IR72049-B-R-22-3-1-1) was the highest yielding genotype followed by G5 (IR68652-3B-30-2) and

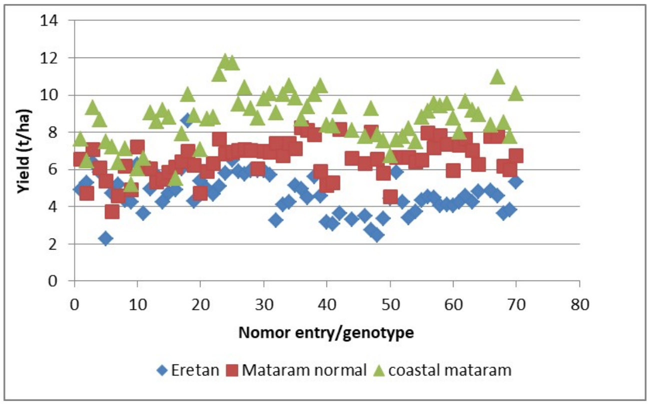

Figure 1. Scatter plot of grain yields of genotypes at three different environments.

Table 1. Characteristic of soil on farmer's field used for trial sites, in 2009.

Sites	Soil texture			pH		Salinity		Corresponding EC se dS/m*
	Sand	Silt	Clay	H_2O	KCl	dS/m	mg/l	
Eretan, Indramayu (saline condition)	22	20	58	6.9	5.9	0.9-2.04	434-1010	>12.2
Mataram (saline conditon)	28	38	34	8.3	7.0	0.1-0.5	71-252	1.9-4.5
Mataram (normal condition)	43	32	25	8.4	6.9	0.02-0.05	11-21	<0.95

*Shaw (2001)

G3(IR58427-5B-15), and in coastal Mataram, G36(IR 77674-3B-8-2-2-13-4-AJY 2) was the highest yielding genotype, followed by G42(IR 59418-7B-21-3) and G37(IR 77674-3B-8-2-2-14-2-AJY3). Under normal soil condition of Mataram, the highest yielding genotype was G24 (IR 77674-3B-8-2-2-8-3-AJY4) followed by G25(IR 77674-3B-8-2-2-12-5-AJY2) and G37(IR 77674-3B-8-2-2-14-2-AJY 3).

The analysis variance showed that the grain yield was significantly affected by environment, by genotypes, and by G x E interaction (Table 2).

The AMMI analysis of variance of grain yield showed that 45.2% of the total sum of squares was attributable to environmental effect, and 16.78% to genotype effects and 13.68% to G x E effects. Large sum squares for environments indicated that the environments were diverse causing most of the variation in grain yields. The magnitude of the G x E was less than that of genotypes, indicating that there were substantial differences in genotypic responses across environments.

The result from AMMI analysis (Table 2) showed that the first principal component analysis axis (IPCA1) captured 63.9% of the interaction sum of squares. The second principal component analysis (IPCA2) explained the 36.1% of the G x E sum of squares. The mean squares for both the IPCA 1 dan IPCA 2 were significant at P=0.005, It suggested the two principal component analyses of the interaction was the best predictive model and very good to explain the interaction of the 67 genotypes with the three environments. This model explained 100% of the total G x E. Zobel *et al.* (1988) supposed that AMMI with only two interaction principal component axes was the best predictive model. Gauch and Zobel (1996), Yan and Rajcan (2002) suggested that the most accurate model for AMMI can be predicted by using the first two PCAs.

Figure 2 showed the AMMI 1 biplot (IPCA1 vs additive effect from genotypes and environments), while Figure 3 showed AMMI 2 the interaction two biplots. According to Olievera *et al.* (2013), the y-axis (IPCA1 by AMMI 1) represented stability, while AMMI 2 analysis revealed stable environments and genotypes located near the origin with a low score for the two axes of the interaction (IPCA1 and IPCA2) to the interaction.

Table 2. Analyses of variance based AMMI model for grain yields in three environments.

Source of variance	DF	Sum of square	Mean of square	% explained
Environment	2	1009.28	504.64**	
Error 1	6	112.30	18.72**	
Genotype	66	375.05	5.68**	
Env. x Genotype	132	306.38	2.31**	
IPCA1	67	195.72	2.92**	63.9
IPCA2	65	110.66	1.70**	36.1
Residual	395	432.30	1.09	
Total	602	2235.33	3.71	
CV (Coeficient of variance, %)	15			

In the AMMI1 model (Figure 2), the genotypes located in the same *x* horizontal axis value had the same main effect, while the vertical axis represented the G x E effect (Sholihin 2015). The positive and negative IPCA scores showed the relative G x E effect against the environment. Regarding the environments, Mataram (both E2 and E3) had a lower contribution to the interaction compared to Eretan environment (E1). Environment E2 (Mataram normal) was the most stable environment. Environmental stability is important for demonstrating the reliability of genotype ordering in a given environment concerning the rating for the environment in question (Oliveira *et al.* 2013). In the case of the tested genotypes, the average yield is higher than the overall mean only in the Mataram coastal saline (E3).

Based on Table 1, the coastal Mataram (E3) in Figure 2 was corresponding with a more favorable environment compared to normal Mataram condition (E2), while Eretan (E1) corresponding with the stress condition (E1). The data of the soil analysis showed that three places were different in their soil texture. Another micro-climate component which was not observed during the trials might contribute to the environment differential.

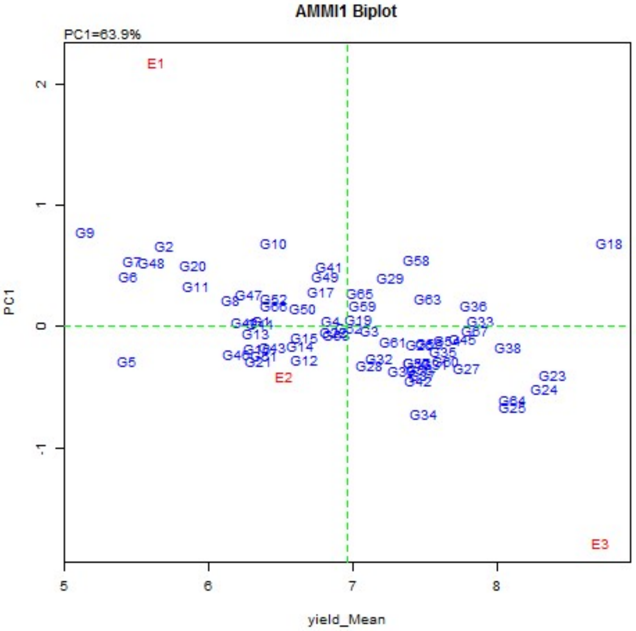

Figure 2. Ammi1 biplot of main effect and interactions (model fit 94.7%).

The trial site in coastal Mataram had higher electrical conductivity value, but the level of EC did not affect the grain yield. It was not surprising since the EC soil in coastal Mataram during transplanting was only 1-9 to 4.5 dS/m, which would not affect the seedling growth. The genotypes tested in these trials were salinity tolerance lines during the seedling stage at 12 dS/m, except for the checks. It supposed that there was no stress during the initiation panicle to flowering, which was the most growing sensitive stage for the grain yield under salt stress. The overall mean yield for every environment was high (>5 t/ha).

AMMI1 Biplot (Figure 2) showed that G58 (IR 74099-AC 7) and G34 (IR 77664-B-25-1-2-1-3-12-3-AJY 1) produced almost the same grain yield, but they had different G x E effect. The genotype G34 (IR 77664-B-25-1-2-1-3-12-3-AJY1) had a negative G x E effect, but G52 (IR72593-B-13-3-3-1) had a positive G x E effect. It supposed that the Eretan environment (coded by E1) represented higher salinity (with positive IPCA value) or higher G x E positive effect, while Mataram coastal area (E3) had the negative G x E effect, and Mataram normal condition (E2) was considered as less G x E effect.

Genotype 18(IR72049-B-R-22-3-1-1) produced the highest grain yield (8.55 t/ha), while G9 produced the lowest (5.15 t/ha), Other genotypes with average yield >8 t/ha were G18 (IR72049-B-R-22-3-1-1), G23 (IR 77674-B-20-1-2-1-3-6-4-AJY1), G24 (IR 77674-3B-8-2-2-8-3-AJY4), G25 (IR 77674-3B-8-2-2-12-5-AJY2), G38 (IR 77674-3B-8-2-2-14-2-AJY4) and G67 (CSR-90IR-2).

Using Figure 2 (AMMI1) and Table 2, it showed that G62 (IR 76397-2B-6-1-1-1-1, 6.97 t/ha), G44 (IR 68144-2B-2-2-3-3, 6.36 t/ha), G3 (IR58427-5B-15, 7.12 t/ha), G40 (IR 51337-2B-9-2B-2-2, 6.25 t/ha), G22 (IR 77644-B-9-3-3-2-1-15-2-AJY4, 6.86 t/ha), G1 (CSR28, 6.37 t/ha), G33 (IR 77664-B-25-1-2-1-3-12-5-AJY 1, 7.88 t/ha), G4 (IR65833-4B-17-1-3, 6.85 t/ha), G19 (IR73055-8-1-1-3-1, 7.03 t/ha), G13 (IR71895-3R-9-3-1, 6.32 t/ha) were the top ten stable genotypes (IPCA1 score close to zero). While G67 (Siak Raya, 7.85 t/ha) was the second most stable genotype after G62 (IR 76397-2B-6-1-1-1-1). Among of these genotypes, genotype G67, G3, G33 and G19 produced higher yield than the overall mean (6.96 t/ha).

Figure 3 showed the Biplot IPCA1 and IPCA2 (AMMI2) for the environment based on the grain yield. The E1 axis which represented the Eretan environment had a positive IPCA1 score and a negative IPCA2 score. The E2 axis represented the normal Mataram environment. It was located at negative IPCA1 and positive IPCA2, while the E3 axis represented coastal Mataram. Both IPCA scores for this axis were positive values. AMMI2 analysis revealed stable environments and genotypes located near the origin with a low score for the two axes of the interaction (IPCA1 and IPCA2) (Oliveira *et al.* 2013).

Based on Figure 3, the position of G3 (IR58427-5B-15, 7.12 t/ha), G4 (IR65833-4B-17-1-3, 6.85 t/ha), G62 (IR 76397-2B-6-1-1-1-1, 6.97 t/ha), G19 (IR73055-8-1-1-3-1, 7.03 t/ha), G22 (IR77644-B-9-3-3-2-1-15-2-AJY4, 6.86 t/ha) was most closed to (0,0) axis compared to others. It is difficult to locate the relative rangking among of genotypes in terms of yield stability, using Figure 3 only.

ASV (Ammi Stability Values) measure was proposed by Purchase *et al.* (2000) to quantify and classify genotypes according to their yield stability because AMMI analysis does not provide a quantitative measure of stability (Oliveira *et al.* 2014). An ASV is the distance of the varieties from point zero of the scatter diagram (IPCA1 vs. IPCA2). The IPCA1 score contributes more to the sum of squares for the G×E interaction, therefore it is weighted by the proportional difference between the scores of IPCA1 and IPCA2 to compensate for the relative contribution of IPCA1 and IPCA2 to the total sum of squares of the interaction. In the ASV method, a genotype with least ASV score is the most stable (Farshadfar *et al.* 2011).

The ASV value ranged from 0.08-1.19 (Table 3). The ASV for the check Siak Raya, Dendang, and FL478 were 0.35, 0.25, and 0.40, respectively. Twelve genotypes had ASV values less than 0.25 and twenty genotypes had ASV values less than 0.35. It supposed that genotypes with ASV value less than the checks were stable genotypes as good as the checks. Based on the ASV value, Dendang was the most stable check variety and the most stable genotypes were G22 (IR 77644-B-9-3-3-2-1-15-2-AJY4, 6.6

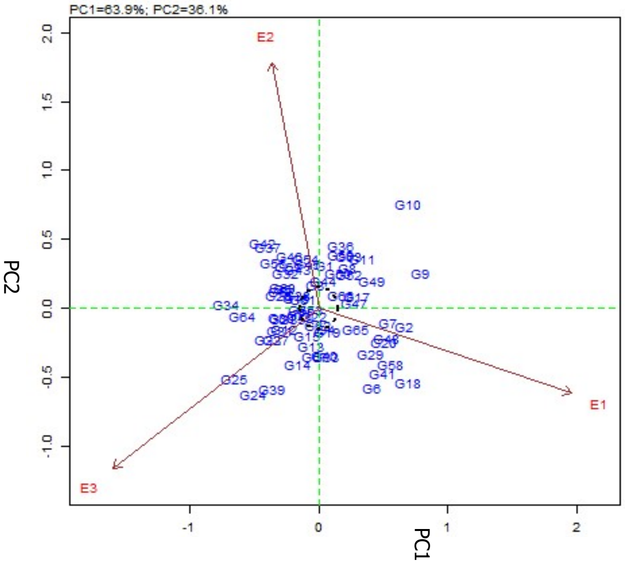

Figure 3. The Ammi2 Model the interaction biplot.

t/ha), Other nine genotypes having small ASV value were G55 (IR 72593-B-18-2-2-2, 6.55 t/ha), G64 (IR 76397-2B-6-1-1-1-1, 6.67 t/ha), G38 (IR 77674-3B-8-2-2-14-2-AJY 4, 7.84 t/ha), G49 (IR 71895-3R-60-3-1, 5.56 t/ha), G19 (IR73055-8-1-1-3-1, 6.47 t/ha), G35 (IR 77674-3B-8-1-3-13-2-AJY2, 7.36 t/ha), G26 (IR7674-3B-8-2-2-14-1-AJY5, 7.47 t/ha), G60 (IR74099-AC7, 6.25 t/ha) and G30 (IR77664-B-25-1-2-1-3-12-4-AJY1, 7.58 t/ha).

Figure 3 could also show the relative performance of particular genotypes in the specific environment. Genotype which was closed to a line drawn connected from a specific environment to the perpendicular of IPCA1 and IPCA 2 (0,0) point was considered to have a high G x E. Genotype 18 (IR72049-B-R-22-3-1-1), G6 (IR70023-4B-R-12-2-3-1), G41 (IR 51499-2B-29-2B-1-1), G7 (IR70023-4B-R-12-3-1), G2 (IR50184-3B-18-2B-1), G48 (IR 71897-3R-1-1-2), and G20 (IR72580-B-24-3-3-3-2) were relatively far from (0,0) axis and closed to E1 lines, indicated having better adaptability to Eretan environment. While G25, G24, and G29 were more favorable to the coastal Mataram environment (E3). Genotype 42 (IR59418-7B-21-3), G37 (IR 77674-3B-8-2-2-14-2-AJY 3) was very favorable for E2 (normal Mataram environment).

Genotype G23 (IR 77674-B-20-1-2-1-3-6-4-AJY1, 7.95 t/ha), G25 (IR 77674-3B-8-2-2-12-5-AJY2, 8.37 t/ha), G24 (IR 77674-3B-8-2-2-8-3-AJY4), G38 (IR 77674-3B-8-2-2-14-2-AJY4, 8.08 t/ha), and G64 (CSR-90IR-2, 8.11 t/ha) produced very high yield (>8 t/ha) over to the overall mean. The ASV score varied showing differences of the adaptability. Genotype 38 and 23 was more stable compared to G24 and G25. The ASV value of G23 (IR 77674-B-20-1-2-1-3-6-4-AJY1), G25 (IR 77674-3B-8-2-2-12-5-AJY2), G24 (IR 77674-3B-8-2-2-8-3-AJY4), G18 (IR72049-B-R-22-3-1-1) were higher compared to others, showing relative unstable, indicating a specific environment genotypes.

Based the AMMI1 model (Figure 3), which explained 63.9% of the variance, Siak Raya was the second most stable genotype among the groups, while using AMMI2 model which explained 100% of variance and ASV value, the ranking of yield stability of Siak Raya was the 21st, while Dendang showed the most stable check variety. This was in the same direction as Gauch and Zobel (1996), Yan and Rajcan (2002) who were suggesting that the most accurate model for AMMI can be predicted by using the first two PCAs. The ASV parameter has been

Table 3. The mean yield for each genotype, IPCA1 and IPCA2 score and ASV value.

Line	Designation	Mean	PC1	PC2	ASV	Line	Designation	Mean	IPCA1	IPCA2	ASV
G1	CSR28	6.37	**0.05**	0.31	**0.32**	G36	IR 77674-3B-8-2-2-13-4-AJY 2	7.84	0.17	0.45	0.51
G2	IR50184-3B-18-2B-1	5.69	0.66	-0.13	0.89	G37	IR 77674-3B-8-2-2-14-2-AJY 3	7.49	-0.40	0.45	0.69
G3	IR58427-5B-15	7.12	**-0.03**	0.17	**0.17**	G38	IR 77674-3B-8-2-2-14-2-AJY 4	**8.08**	-0.16	0.09	**0.23**
G4	IR65833-4B-17-1-3	6.85	**0.06**	-0.15	**0.17**	G39	IR 78806-B-B-16-1-2-2-AJY 1	7.34	-0.36	-0.58	0.76
G5	IR68652-3B-30-2	5.43	-0.28	0.15	0.40	G40	IR 51337-2B-9-2B-2-2	6.25	**0.04**	-0.34	0.34
G6	IR70023-4B-R-12-2-3-1	5.44	0.41	-0.57	0.79	G41	IR 51499-2B-29-2B-1-1	6.84	0.49	-0.47	0.81
G7	IR70023-4B-R-12-3-1	5.47	0.54	-0.11	0.73	G42	IR 59418-7B-21-3	7.45	-0.44	0.47	0.75
G8	IR70023-4B-R-12-3-1-1	6.15	0.23	0.29	0.42	G43	IR 68144-2B-2-2-3-2	6.44	-0.17	0.28	0.36
G9	IR71829-3R-10-3	5.14	0.79	0.26	1.08	G44	IR 68144-2B-2-2-3-3	6.36	**0.03**	0.20	**0.20**
G10	IR71829-3R-28-1	6.45	0.69	0.75	1.19	G45	IR 70870-B-P-2-2	7.76	**-0.09**	0.32	0.34
G11	IR71829-3R-82-1-1	5.92	0.34	0.36	0.58	G46	IR 71829-3R-89-1-1	6.19	-0.23	0.38	0.48
G12	IR71866-3R-1-2-1	6.66	-0.27	-0.15	0.39	G47	IR 71895-3R-60-3-1	6.27	0.27	0.03	0.37
G13	IR71895-3R-9-3-1	6.32	**-0.06**	-0.27	**0.28**	G48	IR 71897-3R-1-1-2	5.60	0.53	-0.21	0.73
G14	IR71907-3R-2-1-1	6.64	-0.16	-0.40	0.46	G49	IR 71991-3R-2-6-1	6.80	0.41	0.20	0.58
G15	IR71907-3R-2-1-2	6.66	**-0.09**	-0.20	**0.23**	G50	IR 72579-B-2R-3-1-1	6.65	0.15	0.26	**0.33**
G16	IR71999-3R-3-2-2-B-1-1	6.34	-0.18	0.08	**0.25**	G51	IR 72579-B-2R-1-3-2	6.38	-0.24	0.30	0.43
G17	IR72046-B-R-8-3-1-2	6.78	0.30	0.09	0.40	G52	IR 72593-B-13-3-3-1	6.45	0.24	0.24	0.40
G18	**IR72049-B-R-22-3-1-1**	**8.78**	0.70	-0.54	1.07	G53	IR 72593-B-18-2-2-2	6.88	**-0.07**	-0.01	**0.09**
G19	IR73055-8-1-1-3-1	7.03	0.06	-0.17	**0.19**	G54	IR 72593-B-3-2-3-3	7.65	**-0.11**	0.36	0.38
G20	IR72580-B-24-3-3-3-2	5.90	0.51	-0.25	0.72	G55	IR 73571-3B-14-2	7.53	**-0.13**	-0.01	**0.17**
G21	IR72046-B-R-8-3-1-3	6.34	-0.28	-0.08	0.38	G56	IR 74095-AC45	7.46	-0.35	0.34	0.57
G22	IR 77644-B-9-3-3-2-1-15-2-AJY4	6.86	**-0.04**	-0.06	**0.08**	G57	IR 74095-AC 64	7.44	-0.29	0.12	0.41
G23	**IR 77674-B-20-1-2-1-3-6-4-AJY1**	**8.39**	-0.39	-0.23	0.57	G58	IR 74099-AC 7	7.44	0.56	-0.41	0.85
G24	**IR 77674-3B-8-2-2-8-3-AJY4**	**8.32**	-0.51	-0.62	0.92	G59	IR 75395-2B-B-19-2-1-2	7.06	0.18	0.39	0.46
G25	**IR 77674-3B-8-2-2-12-5-AJY2**	**8.11**	-0.66	-0.51	1.01	G60	IR 76346-B-B-10-1-1-1	7.64	-0.28	0.16	0.41
G26	IR 77674-3B-8-2-2-14-1-AJY5	7.47	**-0.14**	-0.05	**0.19**	G61	IR 76393-2B-7-1-1-3-1	7.28	**-0.12**	0.07	**0.17**
G27	IR 77674-3B-8-2-2-14-4-AJY1	7.79	-0.33	-0.23	0.50	G62	IR 76397-2B-6-1-1-1-1	6.97	**-0.01**	-0.12	**0.12**
G28	IR 77674-3B-8-2-2-14-4-AJY2	7.12	-0.31	0.10	0.42	G63	TCCP 266-1-3B-10-2-1	7.52	0.24	0.38	0.49
G29	IR 78788-B-B-10-1-2-4-AJY1	7.26	0.41	-0.34	0.63	**G64**	**CSR-90IR-2**	**8.11**	-0.60	-0.06	0.80
G30	IR 77664-B-25-1-2-1-3-12-4-AJY1	7.44	-0.29	-0.06	0.40	G65	IR 66946-3R-178-1-1 (FL 478)	7.05	0.28	-0.15	**0.40**
G31	IR 29	7.57	-0.30	-0.16	0.43	G66	Dendang	6.45	0.18	0.10	**0.25**
G32	IR 66946-3R-178-1-1 (FL 478)	7.18	-0.26	0.26	0.43	G67	Siak Raya	7.85	**-0.02**	-0.35	**0.35**
G33	IR 77664-B-25-1-2-1-3-12-5-AJY 1	7.88	**0.05**	-0.35	0.36	E1	Eretan		5.64	2.18	-0.69
G34	IR 77664-B-25-1-2-1-3-12-3-AJY 1	7.49	-0.72	0.02	0.96	E2	normal Mataram		6.53	-0.41	1.98
G35	IR 77674-3B-8-1-3-13-2-AJY 2	7.63	-0.20	-0.07	**0.28**	E3	saline Mataram		8.72	-1.78	-1.30

used as an auxiliary criterion to define more stable genotypes in other crops such as wheat (Farshadfar *et al.* 2011) and rice (Das *et al.* 2010, Sharifi *et al.* 2017), okra (Alake and Ariyo 2012), yellow passion fruits (Oliveira *et al.* 2014), and cassava (Adjebeng-Danquah *et al.* 2017).

The ASV is comparable with the methods of Shukla, Wricke, Eberhart, and Russell stability methods. AMMI is very effective to explain the genotype and environment interaction. The explanation of the interaction effect using a bilinear model very clearly mapped the adaptability of a particular genotype (Sumertajaya 2007).

The good genotype for the farmer was the stable genotype with high yield. The farmer will adopt a new variety if they are sure it will give a benefit. The new variety will not produce a fluctuated yield (stable) as well as high. Genotype with very high yield in the particular (specific environment) was very useful to develop the variety with specific adaptability. Genotypes with high and stable yield will be reevaluated along with the high yielding genotypes with specific adaptability in the preliminary yield trial in bigger plot size. However other characteristics will be also taken into accounts such as phenotypic acceptance, pest and disease resistance, and grain quality as well.

CONCLUSION

Nine genotypes presented high adaptability and high yield compared to the check varieties Siak Raya and Dendang.

Genotype 25 (IR 77674-3B-8-2-2-12-5-AJY2) and G18 (IR72049-B-R-22-3-1-1) presented high yielding genotype with low stability or specific adaptable genotypes, while G23 (IR 77674-B-20-1-2-1-3-6-4-AJY1) and G38 (IR 77674-3B-8-2-2-14-2-AJY4) performed high yield and stability.

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