Yield Stability Evaluation of Upland Rice Lines Obtained from Anther Culture

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Abstract

The objective of this research was to study the adaptation and yield stability of upland rice lines obtained from anther culture. Ten upland rice doubled-haploid (DH) lines were tested for their potential yield in eight different locations (in Provinces of Lampung, West Java, Central Java, Yogyakarta, East Java - Indonesia) in the rainy season of 2010/2011 along with two check varieties (Way Rarem and Batutegi). In each location, the design was Randomized Complete Block Design with four replicates. The method of Francis & Kannenberg, Finlay & Wilkinson, Eberhart & RusseII and AMMI (Additive Main Effect Multiplicative Interaction) were used to analyze the adaptation and yield stability of the tested DH lines. The results indicated that the line showing the most stable yield in different environment was I5-10-1-1 followed by WI-44, and IG-38. I5-10-1-1 produced 4.01 tons of dry grain per hectare. The line showing the highest yield was WI-44, and this line produced 4.72 tons of dry grain per hectare. Visualization with AMMI showed that IW-56 and IW-67 lines were specifically adapted in Purworejo, O18-b-1 is specifically adapted in Bogor, and IG-19 is specifically adapted in Malang, respectively.

Keywords: upland rice, DH lines, yield stability

Introduction

Efforts to increase the food production, especially rice, through the utilization of dry land can be reached by breeding upland rice, since the high-yielding upland rice varieties may be accepted by farmers. Anther culture has been reported to produce doubled-haploid (DH) plants or pure lines in a short time (Dewi *et al*., 1996). On the contrary, conventional breeding will require a long period of time (more than 5 years) in obtaining pure lines as a result of combining the desirable traits of different varieties or parents. Through anther culture of F1, several number of upland rice DH lines were obtained from previous experiment, i.e. IW-56, IW-67, IG-19, IG-38, and GI-8 lines tolerant to low light intensity or shade (Sasmita *et al*., 2006); III3-4-6-1 and I5-10-1-1 lines tolerant to aluminum toxicity (Herathwati *et al.*, 2009); while O18-b-1 and B13-2e lines tolerant to both shade and Al toxicity (Purwoko, 2007). Those DH lines need to be evaluated further.

Subandi (1981) asserted that in the establishment of superior varieties breeders need to pay attention to the yield stability in a systematic and continuous manner, starting from the formation of the basic population to test varieties. Adaptability evaluation in different growing environments need to be done because of the diversity of land, soil, cultivation, cropping patterns and planting season in Indonesia. The diversity of the growing environment will affect the yield per unit area, because the plant growth is a function of genotype and environment (Allard, 1960). Appearance of plants depends on the genotype and environmental conditions where the plant grew, as well as the interaction between the two. Yield stability evaluation through a series of multi location test is an important stage before the varieties can be released. Therefore, this research was aimed to study the adaptation and yield stability of upland rice DH lines obtained from anther culture in 8 different environments.

Materials and Methods

The yield stability test of upland rice was held at eight locations in the rainy season during October 2010 until April 2011. Testing locations spread across Java and Sumatra, namely: the Taman Bogo - Lampung, Natar - Lampung, Cikarawang Bogor - West Java, Sukabumi - West Java, Indramayu - West Java, Purworejo - Central Java, Wonosari - Gunung Kidul, and Malang - East Java. A total of 12 genotypes were used as test material, which consisted of 10 upland rice DH lines obtained from anther culture, i.e. III3-4-6-1, I5-10-1-1, WI-44, GI-7, O18-b-1, IW-67, IG-19, IG-38, IW 56, and B13-2e, while Batutegi and Way Rarem.were two check varieties used for comparison.

The experimental design was Randomized Complete Block Design with four replicates. An experimental unit consisted of 4 x 5 m^2 plot. Each of the tested genotypes were planted with a spacing of 30 x 15 cm. Observations and data analysis were conducted on dry grain yield per hectare. The method of Francis & Kannenberg, Finlay & Wilkinson, Eberhart & RusseII and AMMI (Additive Main Effect Multiplicative Interaction) were used to analyze the adaptation and yield stability of the tested DH lines.

Results and Discussion

The variance analysis of pooled data at eight test locations showed the occurrence of interaction between lines (genotype) and environment (G × E) (Table 1). The existence of such interactions will cause each lines responded differently to the environment in which testing was conducted. The response was mainly shown by the fluctuations in grain yield. A genotypes or varieties though, will not always produce the same great results if planted in different environments. This is caused by the large diversity of the macro geophysical environment that will provide the large environmental diversity for plant growth as well (Satoto *et al*, 2009).

Table 1. Analysis of variance of pooled data at 8 locations

Source of Variation	df	SS	MS	F value	
Location	7	123.18	17.60	30.68	**
Rep/Location	24	66.29	2.76	4.82	**
Lines	11	123.48	11.23	19.57	**
Lines × Location	77	230.93	3.00	5.23	**
Error	264	151.41	0.57		
Total	383	695.30			

*Notes : ** very significantly different*

The average of dry grain yield of WI-44 is able to outperform other lines and check varieties at two locations, namely Bogor and Malang (Table 2). The average dry grain yield showed that only the WI-44 and IW-67 was able to outperform Batutegi varieties, while Way Rarem varieties only surpassed by WI-44. The difference in average yields between WI-44 with Batutegi was 0.34 tons/ha, where WI-44 was about 7.67% higher than Batutegi. The difference in average yield between IW-56 with Batutegi was 0.01 tons/ha or approximately IW-56 was only 0.2% higher than

Batutegi. However, the difference in average yields between WI-44 with Way Rarem was 0.1 tons/ha or WI-44 approximately 17.2% higher than Way Rarem.

Tabel 2. The average dry grain yield (tons/ha) of upland rice DH lines in every test location

DH Lines	LOCATION								Yield Average (tons/ha)
	Indra-mayu	Wono-sari	Purwo-rejo	Suka-bumi	Bogor	Malang	Lam-pung	Taman Bogo	
III3-4-6-1	2.95	2.39	4.88	2.59	1.52	3.11	2.79	3.36	2.95
I5-10-1-1	2.88	3.44	4.62	4.70	4.81	4.11	2.99	4.51	4.01
WI-44	3.24	3.74	5.55	5.69	5.40	5.98	4.15	4.02	4.72
GI-7	2.72	2.60	2.53	3.73	5.16	5.10	2.68	3.69	3.52
O18-b-1	2.17	2.41	3.19	3.45	5.04	3.58	2.68	2.52	3.13
IW-67	3.14	4.35	6.94	5.08	4.14	3.90	3.76	3.85	4.39
IG-19	1.86	3.61	2.66	3.40	3.79	4.32	2.26	4.48	3.30
IG-38	2.06	3.38	3.28	3.70	2.89	4.51	2.31	4.13	3.28
IW-56	2.51	4.39	6.81	4.14	2.69	3.25	3.53	3.21	3.82
B13-2e	2.91	2.52	3.54	4.07	4.22	4.66	4.00	4.41	3.79
Batutegi	3.01	3.14	5.89	4.16	3.04	5.63	4.66	5.54	4.38
Way Rarem	3.79	3.87	4.35	6.95	3.46	5.33	4.99	4.24	4.62
Average	2.77	3.32	4.52	4.30	3.85	4.46	3.40	4.00	3.81
CV (%)	24.0	23.2	20.6	15.6	23.1	10.6	12.6	25.7	

The parameters of stability of dry grain yield of upland rice DH lines from eight locations are presented in Table 3. Lin *et al.*(1986) suggested three concepts of stability. A genotype is considered to be stable if: (1) the variance among environment is small, (2) the response to its environment is parallel to the mean response of all genotypes in the trial, (3) residual mean square (MS) from the regression model on the environmental index is small.

Tabel 3. Parameters of stability of dry grain yield of upland rice DH lines from eight locations

DH lines	Yield (t/ha)	SD_i	CV_i	b_i		δ_2	R_i^2
III3-4-6-1	2.95	1.09	32.51	0.64	*	1.04	0.31
I5-10-1-1	4.01	0.74	19.74	1.10	ns	0.73	0.64
WI-44	4.72	1.02	22.17	1.52	*	1.25	0.43
GI-7	3.53	1.21	31.16	0.77	*	1.40	0.29
O18-b-1	3.13	1.01	29.55	0.76	*	0.98	0.37
IW-67	4.39	1.00	26.56	1.31	*	1.58	0.32
IG-19	3.30	1.23	28.85	0.84	ns	1.05	0.37
IG-38	3.28	1.10	25.70	1.02	ns	0.82	0.47
IW-56	3.82	1.38	35.92	1.18	ns	2.19	0.20
B13-2e	3.79	1.04	19.71	0.78	*	0.65	0.67
Batutegi	4.22	1.20	27.98	1.17	ns	1.75	0.29
Way Rarem	4.62	1.15	24.42	0.90	ns	1.47	0.35
Rata-rata	3.81			1.00			

Notes : SDi= Standard deviation of genotype; CVi=Coeficient of variance of genotype;, bi= Coefficient of regression of genotype, value of b_i * (significantly different with 1), ns (not significantly different with 1); δ_2=parameter of deviation;, R_i^2=Coefficient of determination.

Francis & Kanennberg (1978)

Francis and Kanennberg (1978) measure the stability by using the coefficient of variability (% CV_I) of each genotype tested in multiple environments. The small values of its coefficient of genotype diversity meant that the genotype is more stable. Moedjiono and Mejaya (1994) categorized the value of the coefficient of genotype diversity in four groups, namely low (<25%), rather low (25 -50%), rather high (50-75%), and high (75-100%). Therefore, based on those criteria the DH lines tested in this study fell into of low and rather low groups. I5-10-1-1, WI-44, B13-2e, and Way Rarem have a low coefficient of genotype diversity, thus classified as stable.

Finlay and Wilkinson (1963)

Stability analysis of Finlay and Wilkinson (1963) is a method of measurement stability that is based on the regression coefficient (b_i) between the average yields of a genotype with a general average of all genotypes tested in all test environments. This analysis can explain the phenomenon of stability and adaptability of a genotype. Finlay and Wilkinson categorize standard b_i values of stability in the three groups, namely (1) the stability is below the average, if the value of $b_i > 1$, (2) stability is equivalent the average, if the value of $_{bi} = 1$, (3) stability is above the average, if the value of $b_i <1$.

Based on those criteria, Batutegi and Way Rarem and also three DH lines had b_i values not significantly different from 1, i.e. I5-10-1-1, IG-19, IG-38, and IW-56. Those DH lines were categorized as a stable line, which meant the lines will be able to adapt to the large environment. Lines with the stability below the average were WI-44 and IW-67 with the b_i of 1.52 and 1.31, while the lines with the stability above the average were III3-4-6-1, GI-7, O18-b-1, and B13-2e with b_i values of 0.64, 0.77, 0.76, and 0.78, respectively. Lines that have below-average stability are sensitive to environmental changes and adapt to particular environmental benefit (favorable). The lines which have above average stability are generally able to adapt to marginal environments.

Eberhard dan Russel (1966)

Stability analysis of Eberhard and Russell (1966) is a measure of stability based on the deviation from the regression of the average value of genotype on the environmental index. A genotype is stable if residual mean square (MS) from the regression model on the environmental index is small. Parameter stability seen from the deviation value (δ_2) and coefficient of determination (R_i^2) of the tested genotypes. Model stability of a genotype is good if it has little δ_2 value and large R_i^2 value (approaching 1).

Based on these parameters, two DH lines namely B13-2e and I5-10-1-1 had the smallest value of δ_2, i.e. 0.65 and 0.73 (Table 3). Coefficient of determination (R_i^2) from these two lines also had the largest value among lines and other varieties, i.e. 0.67 and 0.64. Therefore, the regression model used to estimate the stability of those two lines are better than the other lines.

AMMI (Additive Main Effect Multiplicative Interaction)

Due to limited visualization of graphs that are only capable of displaying two-dimensional graph, then the model described in this paper is AMMI2. AMMI2 model can explain the diversity of the interaction effect up to 70.98%. Bi-plot of interaction affects AMMI2 model for the dry grain yield of upland rice DH lines are presented in Figure 1. The bi-plot of principal components 1 and 2 can explain the main components of lines which are stable at all location test or specific to a particular location. Mattjik and Sumertajaya (2000) states that a line or genotype is said to be stable when close to the axis or point (0,0). The lines or genotypes that are far away from the axis but close to the line location, then the lines were classified as specific location lines. Based on these, lines that are stable at all location test are I5-10-1-1, WI-44, IG-38, and Way Rarem. IW-56 and IW-67 were specific to the location of Purworejo, O18b-1 line-specific for the location of Bogor. IG-19 is specific to the location of Malang.

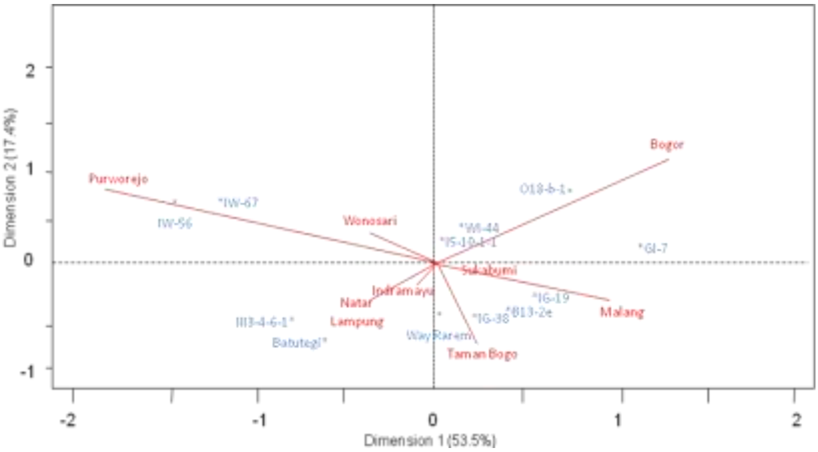

Figure 1. Bi-plot of interaction effects AMMI2 model for the dry grain yield of upland rice DH lines derived from anther culture

Conclusions

The DH line showing the most stable yield in different environment was I5-10-1-1 followed by WI-44, and IG-38. Visualization with AMMI showed that IW-56 and IW-67 lines were specifically adapted in Purworejo, O18-b-1 was specifically adapted in Bogor, and IG-19 was specifically adapted in Malang.

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