Yield Stability of Ten Hybrid Rice Combinations Derived from Introduced CMS and Local Restorer Lines

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ABSTRAK. Stabilitas Hasil 10 Kombinasi Padi (*Oryza sativa* L.) Hibrida Turunan Galur Mandul Jantan Introduksi dan Galur Pemulih Lokal. Salah satu masalah yang dihadapi dalam pembuatan padi hibrida adalah ketidakstabilan ekspresi heterosis tanaman. Untuk mempelajari potensi hasil dan menganalisis stabilitas hasil padi hibrida, uji multilokasi diperlukan. Uji multilokasi 10 kombinasi hibrida harapan telah dilakukan di sepuluh lokasi di Jawa Barat dan Jawa Tengah untuk mengevaluasi penampilannya dibandingkan dengan IR64. Data hasil gabah dianalisis untuk mengetahui adaptasi dan stabilitas kombinasi-kombinasi hibrida yang diuji. Hasil analisis menunjukkan bahwa IR62829A/MTU9992, IR58025A/RHS-412, IR58025A/B10277, IR58025A/B8049F, dan IR58025A/Cisokan memberikan hasil yang stabil pada sejumlah lokasi, yang ditunjukkan oleh koefisien regresi (b) yang tidak berbeda nyata dengan 1. Kombinasi hibrida IR58025A/MTU9992 dan IR58025A/IR65515 hanya beradaptasi dengan baik pada lingkungan optimal, kombinasi hibrida IR58025A/C20R, IR58025A/IR68, dan IR58025A/B10373E dapat beradaptasi dengan baik pada lingkungan suboptimal.

Kata kunci: Adaptabilitas, stabilitas, padi hibrida

ABSTRACT. The weakness of the presently available hybrid rice varieties was the instability of the heterotic expression. To study their yield potential and to analyze their yield stability, multi-location trials of 10 (ten) experimental hybrid rice were conducted in ten locations, in West Java and Central Java provinces, using IR64 as check. Grain yield data were collected and analyzed to evaluate their adaptability and yield stability. The performance of IR62829A/MTU9992, IR58025A/RHS-412, IR58025A/B10277, IR58025A/B8049F, and IR58025A/Cisokan hybrids were stable across locations and were found to be better in terms of the adaptability and yield stability, as indicated by their coefficient of regression value which was not significantly different from one. IR58025A/MTU9992 and IR58025A/IR65515 hybrids were adapted to only favorable growth environment while IR58025A/C20R, IR58025A/IR68, and IR58025A/B10373E were each adapted to sub optimal area.

Keywods: adaptability, stability, hybrid rice

In rice, one criterion in selecting the best line is high yielding potential. The character is complex and controlled by a number of cumulative, duplicate, and or dominant genes, and affected by environment (Reddi *et al*. 1986). Yielding character of hybrid rice is also determined by the level of heterosis of respective hybrid.

In rice breeding, particularly in breeding materials selection and testing strategy, genotype x environment interaction is the main factor and very complicated, yet needs to be understood to identify promising lines. To develop a variety well adapted to a specific environment, a line with very high interaction with environment must be found. On the contrary, if a stable or broad adaptability variety is expected, a line with no or very little interaction is needed.

One experimental hybrid might be identified in yield trials because any hybrid variety performs well in a particular environment. Several methods for analyzing genotype x environment interaction have been developed to determine whether a line has a specific or broad adaptability. One method was formulated by Eberhart and Russel (1966) to study varieties' adaptability and stability. It was designed to recognize stable genotypes with lowest genotype x environment interaction. Availability of stable varieties will decrease the yield variation across locations. The method was then modified by other researchers (Perkins and Jink 1968, Freeman and Perkins 1971, Shukla 1972).

In a breeding program, multi-location trials should be carried out to study yield potential of promising hybrids and to analyze their yield stability based on genetic x environment interaction. The genotype x environment interaction may cause unstable yield of the hybrids across locations (Syafruddin and Saenong 1996). Generally yield variations occur because most hybrid rice combinations grow better in a particular location (Satoto and Suprihatno 1998). Thus, systematic and continuous analysis on yield stability should be made since the beginning of early generation up to multi-locations trials.

Some promising rice hybrid combinations with high yielding potential and resistant or moderately resistant to BPH (brown planthopper), BLB (bacterial leaf blight), and RTV (rice tungro virus) have been identified. Among them are IR58025A/MTU9992, IR58025A/C20R, IR58025A/IR65515, IR62829A/MTU9992, IR58025A/RHS-412, IR58025A/B10277, IR58025A/B8049F, IR58025A/Cisokan, IR58025A/IR68, and IR58025A/B10373E selected from previous Advanced Yield Trials. The hybrids were then further tested in more locations to study their yield potentials, adaptabilities, and yield stabilities.

MATERIALS AND METHODS

The experiments were conducted in ten environments during 2001-2003, i.e. Cianjur in dry season (DS) 2001, wet season (WS) 2001/02, WS 2002/03, and DS 2003, Muara WS 2001/02 and DS 2002; Banyumas DS 2002; Ciamis DS 2002; Sukamandi WS 2002/03; and Kuningan DS 2003. A randomized complete block design with three replications was used in each trial. Ten promising rice hybrid combinations namely IR58025A/MTU9992, IR58025A/C20R, IR58025A/IR65515, IR62829A/MTU9992, IR58025A/RHS-412, IR58025A/B10277, IR58025A/B8049F, IR58025A/Cisokan, IR58025A/IR68, and IR58025A/B10373E were used as testing materials compared to IR64 as check variety. Fertilizer of 300 kg urea/ha, 100 kg TSP/ha, and 100 kg KCl/ha were applied in the field. Twenty-one-day old seedlings were planted, one seedling per hill, with planting space of 25 cm x 25 cm, in 4 m x 5 m plots. Grain yield data were analyzed using F-test and the mean data was analyzed using Least Significantly Different (LSD) and then followed by genotype x environment analysis.

Yield stability was analyzed by Eberhart and Russell method (1966), with the following linear model:

$$Yij = \mu + biIj + \delta ij$$

Yij = mean of the i^{th} genotype at the j^{th} environment
μ = mean of the i^{th} genotype over all environments
bi = regression coefficient that measures the response of the i^{th} genotype to varying environments
Ij = environmental index
δij = deviation from regression of the i^{th} genotype at the j^{th} environment

The tested rice hybrids were classified as stable varieties when regression coefficient was not significantly different from one and regression deviation was not significantly different from zero.

RESULTS AND DISCUSSION

Table 1 shows that coefficient of variation ranged from 4.8% (Cianjur WS 2001/2002) to 15.7% (Muara WS 2001/2002). It means that grain yield data collected were valid for variance analysis.

All tested hybrids except IR58025A/B10373E, yielded over the check variety IR64 at least in one location. Only in two environments, namely Cianjur DS 2001 and Muara WS 2001/02, hybrids performed with no significant difference with the check variety IR64 (Table 1), even though in Cianjur DS 2001, IR58025A/IR65515 yielded 10.3 t/ha or 1 t/ha higher than the check variety.

Grain yield of IR58025A/MTU992 combination was significantly different compared to that of IR64 in seven environments, i.e. Cianjur WS 2001/02, Cianjur WS 2002/03, Cianjur DS 2003, Banyumas DS 2002, Ciamis DS 2002, Sukamandi WS 0202/03, and Kuningan DS 2003 (Table 1). The hybrid combinations IR58025A/C20R, IR58025A/IR65515, IR62829A/MTU9992, IR58025A/RHS-412, IR58025A/B10277, IR58025A/B8049F, IR58025A/Cisokan, and IR58025A/IR68 yielded over the check variety IR64 in 1-4 location(s). It indicates that IR58025A/MTU9992 had the highest yield potential in different environments, so the hybrid combination is potential to be further

Table 1. Grain yield (t/ha) and environment index of ten hybrid rice combinations in ten testing locations, 2001-2003.

Hybrid	Environment										
	1	2	3	4	5	6	7	8	9	10	Mean
IR58025A/MTU9992	9.7	7.3*	11.3*	7.1**	5.2	6.9	11.0**	9.9**	8.5*	9.4**	8.6
IR58025A/C20R	9.7	6.0	10.0	6.9**	6.3	7.6*	7.7	6.5	8.3*	6.9	7.6
IR58025A/IR65515	10.3	6.0	11.7	6.7*	6.0	7.1	8.2	7.5	7.7	8.6*	8.0
IR62829A/MTU9992	8.7	5.3	10.3	6.2	5.7	6.7	10.4*	9.6**	8.2*	8.9**	8.0
IR58025A/RHS-412	8.7	8.0**	11.0	6.9**	5.3	6.8	8.4	6.3	7.2	8.0	7.7
IR58025A/B10277	8.7	6.3	10.3	6.9*	5.2	7.3	8.4	8.1*	8.1	7.5	7.7
IR58025A/B8049F	8.7	7.7*	11.0	6.5*	4.8	7.1	6.5	7.2	7.6	6.8	7.4
IR58025A/Cisokan	9.3	6.3	10.7	6.9**	5.3	7.3	7.3	7.1	7.2	7.1	7.5
IR58025A/IR68	6.3	6.3	10.3	6.1	5.2	8.2*	7.6	7.6*	7.6	6.4	7.2
IR58025A/B10373	8.3	6.3	9.7	5.6	5.2	6.5	6.9	7.4	6.5	6.7	6.9
IR64	9.3	5.3	10.0	5.2	5.7	6.8	8.0	6.8	7.6	7.4	7.2
Mean	8.9	6.5	10.6	6.5	5.5	7.1	8.2	7.6	7.7	7.6	7.6
CV (%)	14.8	4.8	9.5	11.5	15.7	11.6	9.6	8.8	12.8	10.9	
Ij	1.28	-1.15	2.97	-1.14	-2.15	-0.49	0.62	0.03	0.06	0.00	

1 = Cianjur DS 2001, 2 = Cianjur WS 2001/02, 3 = Cianjur WS 2002/03, 4 = Cianjur DS 2003, 5 = Muara WS 2001/02,
6 = Muara DS 2002, 7 = Banyumas DS 2002, 8 = Ciamis DS 2002, 9 = Sukamandi WS 2002/03, 10 = Kuningan DS 2003.
Value within column with ***:** significantly different at p = 0.05, and ****:** significantly different at p = 0.01; Ij: Environmental index.

developed. The average yields of ten hybrid combinations ranged from 6.9 to 8.6 t/ha, while that of IR64 was 7.2 t/ha. All hybrids gave yield potential higher than IR64, except IR58025A/Cisokan and IR58025A/B10373E. Environmental index (Ij) of ten environments ranged from -2.16 to 2.97 (Table 1).

According to Eberhart and Russell (1966), environmental index indicate relative land productivity; locations with higher environmental index are more suitable for plant growth than other locations with lower Ij value (Harsanti *et al.* 2003). Adie *et al.* (2004) also stated that land is more productive when its Ij value is higher. Banyumas, and Cianjur in DS were highly productive locations, because their Ij value were relatively high. Other locations had low productivity with the low or zero Ij value (Kuningan). Environment is considered as non-genetic factors which influenced expression of plant phenotypic (Sumarno *et al.* 1993). This phenomenon explains yield variation of hybrid combinations in different locations (Sumarno *et al.* 1993). To Satoto and Suprihatno (1998), genotype x environment interaction contributes highly to yield variation. Lower average of yields and Ij values in Kuningan, might be due to limited rainfall and irrigation, made hybrids tested suffered from drought at flowering stage. High yielding varieties are mostly unstable, and stable varieties generally have low productivity, so stable varieties with low input are more important to be improved.

Performances of hybrids during dry season were generally better than in wet season (Tables 2 and 3). During dry season, the average of grain yield difference from IR64 ranged from –0.3 t/ha (IR58025A/B10373E) to 1.7 t/ha (IR58025A/MTU9992) or -3.2% to 25.3% higher than IR64 (Table 2). On the other hand, during wet season, the average of grain yield difference ranged from -0.24 to 0.93 t/ha or -2.1% to 13.5% showed by the same hybrids (Table 3). The biggest grain yield difference from IR64 was 3.0 t/ha or 44.5% achieved by IR58025A/MTU9992 in Ciamis DS 2002. This hybrid combination performed better compared to the check variety even to the other tested combinations in both dry and wet seasons.

The hybrids showing better performances in dry season were IR58025A/MTU9992, IR58025A/IR65515, IR62829A/MTU9992, IR58025A/B10277, and IR58025A/Cisokan. On the other hand IR58025A/C20R, IR58025A/RHS-412, IR58025A/B8049F, and IR58025A/IR68 performed better in wet season.

The averages of grain yield and stability parameters of the ten tested hybrid combinations and IR64 are presented in Table 4. Coefficient of regression (bi) varied from 0.79 to 1.22. Coefficient of regressions of all hybrid combinations except IR58025A/IR65515 and IR58025A/IR68 were not significantly different from one. Deviation of regression indicates genotypes potential to minimize environmental effects (Takdir *et al.* 1999). Referring Eberhart and Russell (1966), eight hybrid combinations namely IR58025A/MTU9992, IR58025A/C20R, IR62829A/MTU9992, IR58025A/RHS-412, IR58025A/B10277, IR58025A/B8049F, IR58025A/Cisokan and IR58025A/B10373E were stable.

One advantage of regression coefficient as an adaptation determinant is that it enables to determine

Table 2. Grain yield difference compare to IR64 (t/ha) and (%) of experimental hybrids during dry season.

Hybrids	Environment													
	1		4		6		7		8		10		Mean	
	Grain yield difference from IR64													
	(t/ha)	(%)	(t/ha)	(%)	(t/ha)	(%)	(t/ha)	(%)	(t/ha)	(%)	(t/ha)	(%)	(t/ha)	(%)
IR58025A/MTU9992	0.34	3.6	1.87**	35.9**	0.16	2.36	3.03**	38.0**	3.04**	44.5**	2.00**	27.2**	1.74	25.3
IR58025A/C20R	0.34	3.6	1.73**	33.3**	0.86*	12.7*	-0.30	-3.7	-0.30	-4.4	-0.44	-6.0	0.31	6.0
IR58025A/IR65515	1.00	10.7	1.53*	29.4*	0.30	4.43	0.26	3.3	0.64	9.4	1.27*	17.3*	0.83	12.4
IR62829A/MTU9992	-0.66	-7.1	0.97	18.6	-0.10	-1.5	2.46*	30.8*	2.80**	41.0**	1.55**	21.0**	1.17	17.1
IR58025A/RHS-412	-0.66	-7.1	1.73**	33.3**	0	0	0.46	5.8	-0.56	-8.2	0.60	8.15	0.26	5.3
IR58025A/B10277	-0.66	-7.1	1.73**	33.3**	0.50	7.4	0.43	5.4	1.24*	18.1*	0.13	1.77	0.56	9.8
IR58025A/B8049F	-0.66	-7.1	1.30*	25.0*	0.33	4.9	-1.44	-18.0	0.40	5.8	-0.55	-7.5	-0.10	0.5
IR58025A/Cisokan	0	0	1.73**	33.3**	0.53	7.8	-0.67	-8.4	0.27	3.9	-0.22	-3.0	0.27	5.6
IR58025A/IR68	-3.00	-32.1	0.87	16.7	1.43*	21.1*	-0.40	-5.0	0.77*	11.3*	-0.95	-13.0	-0.21	-0.2
IR58025A/B10373	-1.00	-10.7	0.43	8.3	-0.24	-3.5	-1.04	-13.0	0.57	8.3	-0.63	-8.6	-0.32	-3.2
Mean	-0.50	-5.3	1.4	26.7	0.4	5.6	0.3	3.5	0.9	13.0	0.3	3.7	0.52	7.9

1 = Cianjur DS 2001, 4 = Cianjur DS 2003, 6 = Muara DS 2002, 7 = Banyumas DS 2002, 8 = Ciamis DS 2002, 10 = Kuningan DS 2003.

Table 3. Grain yield difference compare to IR64 (t/ha) and (%) of experimental hybrids during the Wet Season.

Hybrids	Locations									
	2		3		5		9		Mean	
	Grain yield difference from IR64									
	(t/ha)	(%)	(t/ha)	(%)	(t/ha)	(%)	(t/ha)	(%)	(t/ha)	(%)
IR58025A/MTU9992	2.00*	37.5*	1.33*	13.3*	-0.49	-8.6	0.88*	11.6*	0.93	13.5
IR58025A/C20R	0.67	12.6	0	0	0.57	9.9	0.68*	9.0*	0.48	7.9
IR58025A/IR65515	0.67	12.6	1.67*	16.7*	0.29	5.1	0.14	1.8	0.70	9.0
IR62829A/MTU9992	0	0	0.33	3.3	-0.02	-0.3	0.64*	8.0*	0.24	2.3
IR58025A/RHS-412	2.67**	50.0**	1.00	10.0	-0.44	-7.7	-0.42	-5.5	0.70	11.7
IR58025A/B10277	1.00	18.8	0.33	3.3	-0.51	-8.9	0.53	7.0	0.34	5.0
IR58025A/Maros	2.34*	43.9*	1.00	10.0	-0.94	-16.4	0.03	0.4	0.61	9.5
IR58025A/Cisokan	1.00	18.8	0.67	6.7	-0.46	-8.0	-0.37	-4.9	0.21	3.2
IR58025A/IR68	1.00	18.8	0.33	3.3	-0.53	-9.2	0	0	0.20	3.3
IR58025A/B10373E	1.00	18.8	-0.33	-3.3	-0.56	-9.8	-1.06	-14.0	-0.24	-2.1
Mean	1.37	25.73	0.77	7.0	-0.31	-5.39	0.12	1.5	0.42	6.33

2 = Cianjur WS 2001/2002, 3 = Cianjur WS 2002/2003, 5 = Muara WS 2001/2002, 9 = Sukamandi WS 2002/2003.

environment adaptable to plant (Harsanti *et al.* (2003). Analysis results indicated that IR58025A/MTU9992 and IR58025A/IR65515 would adapt very well in favorable environment shown by their bi value which was more than 1. IR58025A/MTU9992, IR58025A/RHS-412, IR58025A/B10277, IR58025A/B8049F and IR58025A/Cisokan hybrid combinations had regression coefficients nearest to one so they would adapt in either favorable or sub optimal environments. On the other hand, IR58025A/C20R, IR58025A/IR68, and IR58025A/B10373E, would be adapted in sub optimal environment, because their bi values were lower than one.

Table 4. Regression coefficient and standard deviation of yields.

Hybrids	Yield (t/ha)	St. het on IR64 (%)	bi[1]	Sd[2]
IR58025A/MTU9992	8.63	19.7	1.20 ns	1.96 ns
IR58025A/C20R	7.59	5.3	0.83 ns	1.37 ns
IR58025A/IR65515	7.99	10.8	1.22 *	1.83 ns
IR62829A/MTU9992	8.01	11.1	1.09 ns	1.91 ns
IR58025A/RHS-412	7.65	6.1	0.96 ns	1.57 ns
IR58025A/B10277	7.68	6.5	0.95 ns	1.39 ns
IR58025A/Maros	7.39	2.5	0.99 ns	1.62 ns
IR58025A/Cisokan	7.46	3.5	1.01 ns	1.51 ns
IR58025A/IR68	7.16	-0.7	0.78*	1.44 ns
IR58025A/B10373E	6.92	-4.0	0.88 ns	1.30 ns
IR64	7.21	-	1.05 ns	1.60 ns

[1] ns: not significantly different to one,
[2] ns: not significantly different to zero.
bi: regression coefficient, Sd: deviation of regression.

CONCLUSIONS

1. IR58025A/MTU9992 and IR58025A/IR65515 are adaptable to favorable environments and have the widest adaptability among tested hybrid combinations.
2. IR62829A/MTU9992, IR58025A/RHS-412, IR58025A/B10277, IR58025A/B8049F, and IR58025A/Cisokan hybrid combinations had regression coefficient nearest to one, meaning that they are stable and adaptable to both favorable and sub optimal environments.
3. IR58025A/C20R, IR58025A/IR68, IR58025A/B10373E hybrid combinations were more adaptable to sub optimal environments.
4. IR58025A/MTU9992 is the most potential among tested hybrids combinations.

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