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PERFORMANCE OF PROMISING HYBRID RICE IN TWO DIFFERENT ELEVATIONS OF IRRIGATED LOWLAND IN INDONESIA

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ABSTRACT

The hybrid rice program has been established since early 1990's at the Indonesia Center for Rice Research (ICRR). Twenty-four experimental hybrid rice varieties which have been developed were tested in lowland rice fields in Sukamandi (West Java) and Batang (Central Java) during the dry season and the rainy season of 2012. Randomized complete block design (RCBD) with three replications was used in each location. The results showed that grains yields were affected by locations, seasons, and genotypes. The genotypes x locations x seasons interaction effect was significant; therefore, the best hybrid was different for each location and season. A7/PK36 hybrid has the best performance in Batang during the dry season, while A7/PK40 and A7/PK32 are the best hybrids in the rainy season. In Sukamandi, nine hybrids were identified as better yielder than that of the check cultivar in the dry season, but not so in the rainy season. Using the correlation and path analysis, we found that the number of panicles per hill and the number of filled grains per panicle could be used as selection criteria for yield in hybrid rice.

Keywords: agronomic performance, correlation, hybrid rice, lowland

INTRODUCTION

Rice is an important crop in Indonesia due to its significance as the country's first staple food. To increase rice production, there is a slim probability for further expansion in rice area; hence, vertical increase in rice productivity is a vital option to increase yield. To achieve this goal, conventional inbreed varieties need to be supplemented with the hybrid form of variety. Hybrid rice is expected to gain productivity increase derived from the heterotic effect. This technology has been applied succesfully in China since 1976 (Kueneman, 2006). Indonesia has been active in developing hybrid rice as an alternative strategy to improve rice productivity.

Research on hybrid rice in Indonesia began in 1983 with the aim of exploring prospects and constraints of this technology. Since 1998 the research has been further intensified to breed suitable parental lines and F_1 hybrid from the local germplasm. Up to 2011, Indonesian Center for Rice Research had released 17 hybrid rice varieties with some yield advantage over inbreed varieties, Ciherang and IR64 as popular varieties. However, hybrid rice which has been released is susceptible to pests and diseases, and the heterotic effect was not stable. Breeding programs to improve the resistance of parental lines and the F_1 hybrid have been intensified (Satoto *et al.,* 2013). Parental lines of the hybrids developed in Indonesia are mostly derived from introduced lines, which are more susceptible to stresses as well as pests and diseases. Therefore, it is imperative to develop a hybrid variety using Indonesian parental line, which is well adapted to the local environment by identifiying elit lines as restorer and maintainer (Nugraha *et al*., 2004). Two new CMS/male sterile lines have been developed, namely GMJ4A dan GMJ5A, which are resistant to BPH (Nugraha *et al.,* 2011). Further research has resulted in GMJ6A and GMJ7A male sterile lines which are identified as having good resistance to BLB.

High grain yield of rice has been the primary objective in the breeding programs. The character is complex and controlled by a number of interactive, duplicative, and/or epistatic genes, and is affected by environment (Reddy *et al*., 1986). High yielding character of hybrid rice is

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also determined by the level of heterosis expressed by the hybrid. Chen *et al.* (2007) stated that the super hybrid rice should have the following criteria: good rice quality, wide adaptation, lodging resistance, resistant to main insects and diseases, and the yield exceeds 8% over control varieties in the national trials.

Grain yield is a complex polygenic quantitative trait, greatly affected by the environment. Hence, selection of superior genotypes based on yield may not be effective. Information on the correlation between yield and its components is important to make formulation for selection criteria of yield. Board *et al.* (1997) suggest that the yield components which can be used for the selection criteria are: (i) yield components which have positive correlation and high direct effect on grain yield, (ii) it has large direct effect although less correlated with grain yield, and (iii) characters which have negative indirect effect on grain yield through other characters. The research objectives are to evaluate the grain yield and its components of some promising hybrid rice in lowland rice fields and to analyze the relationship between yield and its components.

MATERIALS AND METHODS

Twenty-four new promising hybrid rice are used as testing materials, compared to Hipa10 as hybrid check variety and Ciherang as popular inbred check variety. These hybrids are derived from one CMS introduction (A7), three CMS improved resistant to pest and desease (GMJ3, GMJ6, and GMJ7), and 13 restorer lines from ICRR. Field experiments were conducted during the 2012 dry season (DS) and rainy season (WS) at two locations i.e. Sukamandi, West Java (Alluvial, 16 m above sea level) and Batang, Central Java (Latosol, 276 m above sea level), Indonesia. Experiments were laid out in a randomized complete block design (RCBD) involving 26 genotypes with three replications. The plot size was 2 x 5 m^2.

The land for the experiments was plowed and harrowed. Fertilizer of 300 kilos of urea/ha, 100 kilos of TSP/ha, and 100 kilos of KCl/ha were applied following the recommended time and doses. Twenty-one day old seedlings were planted in each designated plot, using one-two seedling per hill, with planting space of 20 x 20 cm. In the 2 x 5 m plot, there were ten rows with 25 hills per row. Replanting when needed was done a week after transplanting. Hand weeding was done when weeds were observed. Standard cultural practices were followed. The crop was protected from insect pest and diseases using chemical control as needed. Harvesting was done manually when 85% of the grains in the upper portion of the panicle were yellow and those at the base are at hard dough stage. Each plot was harvested after cutting one border of row, off-type and abnormal plants. Grain yield and yield components, (panicle length at harvest, number of productive tillers per hill, number of filled and unfilled grains per panicle, and weight of 1,000 grains) were recorded. Grain yield data and yield components were analyzed using SAS (version 9.1.3) and the analysis of variance in RCBD was used to determine treatment differences using the procedure as described by Gomez (1985). Hybrid yield performance was compared with check varieties based on least significant difference (LSD) value at the 5%. Partitioning the correlation coefficient of characters into direct and indirect effects was carried out using the procedure described by Singh and Chaudary (1979).

RESULTS AND DISCUSSION

The combined analysis of variance revealed that the genotype x locations, and genotype x location x season interaction were significant for yield and 1000-grain weight, implying the differential response of genotypes to locations, and to seasons in each location (Table 1). All characters were affected by seasons, while effect of locations and genotypes were significant for yield, panicle length, number of unfilled grain, and 1000-grain weight. However, number of panicle and number of filled grain per panicle were not affected by locations or genotypes.

Performance of Agronomic Traits

The data on mean values and each location for number of panicle per hill (Table 2) showed that all hybrids except GMJ3/PK35 and A7/PK40 produced the same number of panicle per hill as that of Hipa10 and Ciherang. Both hybrids produced significantly higher (15) panicle per hill as compared to 14 and 13 panicle per hill of Hipa10 and Ciherang. Number of panicles per hill is an important yield component in rice. The hybrid with low tillering capacity is not required in transplanted rice culture.

Generally, larger panicle is associated with high number of grains/panicle resulting in higher productivity. The five hybrids having panicle significantly longer than Ciherang (24.8 cm) were GMJ6/PK32, A7/PK38, A7/PK36, A7/PK21, and GMJ7/PK40. The number of grains/panicle consists of number of filled and unfilled grains/panicle. There were three hybrids resulted significantly in more number of filled grains/panicle than Hipa10 (135); while hybrid A7/PK21 produced significantly more number of filled grains/panicle than Hipa10 and Ciherang (142). Another hybrid produced equal or less number of filled grains per panicle than both of check varieties (Table 3).

The 1000-grain weight in the hybrids ranged from 22.8-29.5 grams (Table 4). None of the hybrids showed significantly higher or lower than Hipa10 (27.1 g) and Ciherang (26.6 g). Hybrids A7/PK37 and GMJ6/PK38 produced the minimum 1000-grain weight (22.8 g). Hybrid GMJ3/PK42 produced the highest (29.5 g) 1000-grain weight. Eight hybrids look more like Ciherang, the most popular rice inbred in the farmers, namely A7/PK99, A7/PK37, A7/PK38, A7/PK36, A7/PK21, A7/PK40, A7/PK42 and A7/PK32. Similarly, 1000-grain weight is also an important component that contributes towards the increase in yield. In Indonesia, farmers will be more interested in developing hybrid varieties if they have the same shape and size as Ciherang.

Performance of Grain Yield

In average, the grain yield of the hybrid rice was higher in dry season compared to rainy season, while the grain in Sukamandi was also higher than in Batang. In Sukamandi, there were nine hybrid rice which gave higher yield compared to Ciherang as check cultivar during the dry season 2012, but none of the hybrids were better than Ciherang during the rainy season. In Batang, there was one hybrid (A7/PK36) which is better than Ciherang in dry season, while two hybrids (A7/PK40 and A7/PK32) were better than Ciherang in the rainy season.

The grain yields of the hybrids in the dry season ranged from 4.3 t ha^{-1} (GMJ3/PK43) to 9.4 t ha^{-1} (GMJ7/PK40) with an average of 7.1 t ha^{-1}, while in the rainy season ranged from 3.1 t ha^{-1} (GMJ6/PK38) to 7.9 t ha^{-1} (A7/PK40) with an average of 5.2 t ha^{-1}. The grain yield in the dry season was found higher than in the rainy season. The hybrids showing better performance in the dry season were GMJ7/PK37, A7/PK35, A7/PK37, A7/PK36, A7/PK21, A7/PK40, A7/PK42 and GMJ7/PK40 (Table 3). Standard heterosis is defined as the amount by which a hybrid exceeds the most popular variety. The hybrids gave standard heterosis from 16.1% (GMJ7/PK37) to 25.4% (GMJ7/PK40). None of the hybrids showed better performance than Ciherang in the rainy season except A7/PK40. This hybrid gave grain yield 7% higher over Ciherang.

Table 1. Combined analysis of variance of yield and agronomic traits of 26 hybrids of rice grown in two locations and two seasons, 2012

Source of variance	**Df**	**Mean square characters of:**					
		Grain yield	**Number of panicle/hill**	**Panicle lenght**	**Number of filled grains/ panicle**	**Number of unfilled grains/ panicle**	**1000-grain weight (g)**
Location (L)	1	121.825**	0.003 ns	26.893**	9,614.821 ns	10,698.490**	9.520**
Season (S)	1	124.464**	69.260**	119.635**	16,661.539*	5,275.926**	162.115**
LxS	1	0.442ns	24.260**	77.202**	151,184.051**	51,461.696**	364.652**
Error *a*	8	1.182	15.929	5.646	17,763.218	1,111.093	8.325
Genotype (G)	25	5.355**	4.520 ns	8.578*	4,940.274 ns	1,645.600*	15.097*
LxG	25	2.701*	3.797 ns	2.790 ns	2,118.914 ns	395.884 ns	3.531**
SxG	25	2.396 ns	2.000 ns	1.466 ns	2,124.392 ns	572.320 ns	2.948 ns
LxSxG	25	5.860**	1.613 ns	1.496 ns	1,756.265 ns	1,260.462*	2.349 ns
Error *b*	200	0.622	1.179	1.957	2,017.228	276.936	1.158

Remarks: * = Significant at 5% level ; ** = Significant at 1% level; ns = Non significant at 1% level

Table 2. Number of panicle per hill and panicle lenght of 26 hybrids rice grown in two location and two season, 2012

No.	Genotypes	Number of panicles per hill at:				Mean	Panicle lenght (cm) at:				Mean
		Batang		Sukamandi			Batang		Sukamandi		
		DS	WS	DS	WS		DS	WS	DS	WS	
1.	GMJ6/PK32	13.5	12.5	12.3	13.9	13.1	28.8	28.8	28.9	28.0	28.6
2.	GMJ7/PK99	13.7	13.2	16.3	12.0	13.8	28.4	27.2	27.9	28.5	28.0
3.	GMJ3/PK39	14.7	14.1	15.3	13.2	14.3	27.1	26.4	28.1	27.3	27.2
4.	GMJ3/PK99	13.8	13.0	14.9	12.8	13.7	26.7	26.1	27.3	28.4	27.1
5.	GMJ3/PK35	14.9	14.5	16.7	14.4	15.1	28.4	26.3	28.0	28.0	27.7
6.	GMJ7/PK37	13.4	13.0	14.0	13.5	13.5	27.0	26.8	27.7	29.4	27.7
7.	GMJ7/PK33	14.5	14.3	12.5	12.8	13.5	27.8	27.7	27.4	29.6	28.1
8.	A7/PK99	14.9	14.3	15.5	12.7	14.4	27.5	26.7	27.6	29.3	27.8
9.	A7/PK35	14.4	9.4	13.6	14.0	12.8	26.0	27.0	27.1	29.2	27.3
10.	A7/PK37	14.6	9.5	13.3	12.7	12.5	27.7	27.2	28.1	31.6	28.6
11.	A7/PK38	13.6	13.9	16.9	14.1	14.6	27.1	27.7	27.7	30.8	28.3
12.	A7/PK36	15.2	15.6	14.9	13.5	14.8	27.5	27.6	27.4	30.4	28.2
13.	A7/PK21	13.9	13.4	12.1	10.9	12.6	28.5	27.4	28.7	29.2	28.4
14.	GMJ3/PK40	14.1	13.9	14.1	12.9	13.8	26.5	25.7	26.7	28.2	26.8
15.	A7/PK40	14.3	13.8	19.1	13.4	15.1	26.9	27.2	28.1	29.5	27.9
16.	GMJ3/PK42	12.6	12.7	13.5	13.4	13.1	26.7	21.8	27.5	28.4	26.1
17.	A7/PK42	14.9	14.8	14.8	13.6	14.5	27.3	27.3	27.8	28.2	27.6
18.	GMJ3/PK43	13.4	13.4	13.1	13.2	13.3	26.2	26.3	26.4	29.5	27.1
19.	GMJ3/PK97	13.4	13.1	14.7	12.4	13.4	26.6	25.9	27.2	27.8	26.9
20.	GMJ3/PK32	13.0	12.4	14.4	12.8	13.2	27.0	26.8	27.2	27.9	27.2
21.	A7/PK32	13.3	12.7	16.0	13.9	14.0	27.2	27.4	27.7	29.5	28.0
22.	GMJ7/PK40	14.9	14.5	14.2	12.9	14.2	28.3	27.3	28.1	29.7	28.4
23.	GMJ6/PK36	12.3	13.7	15.5	12.2	13.4	27.3	27.7	24.1	29.0	27.0
24.	GMJ6/PK38	14.5	14.1	14.4	12.9	14.0	26.5	25.8	22.9	29.3	26.1
25.	Hipa10 (Check)	14.2	14.0	16.1	12.1	14.1	26.5	27.5	26.8	29.0	27.5
26.	Ciherang (Check)	13.9	13.3	14.1	12.1	13.3	23.1	24.5	24.8	26.7	24.8
	Mean	14.0	13.4	14.7	13.0	13.8	27.1	26.7	27.2	28.9	27.5
	Mean (location)	13.7		13.9			26.9		28.1		
	Mean (season)	14.3^{a}		12.9^{b}			27.2^{a}		27.8^{b}		
	LSD 5%	1.1	1.1	2.6	1.8	6.6	1.5	2.9	1.0	3.0	3.3
	Cofficient Variation (%)	4.9	4.9	11.0	8.53	8.5	3.5	6.7	2.3	6.3	15.1

Remarks: DS=dry season; WS= wet season; ^{a} and ^{b} are mean of the character for dry and rainy season respectively

Table 3. Number of filled and unfilled grains per panicle of 26 hybrids rice grown in two location and two season, 2012

No.	Genotypes	Number of filled grains/panicle at:				Mean	Number of unfilled grains/panicle at:				Mean
		Batang		Sukamandi			Batang		Sukamandi		
		DS	WS	DS	WS		DS	WS	DS	WS	
1.	GMJ6/PK32	108.6	194.0	172.5	129.7	151.2	61.3	37.4	28.6	58.3	46.4
2.	GMJ7/PK99	141.7	184.4	174.0	116.7	154.2	61.6	42.1	31.0	65.6	50.1
3.	GMJ3/PK39	97.7	162.1	101.0	86.5	111.9	72.0	54.1	76.7	96.8	74.9
4.	GMJ3/PK99	115.6	308.0	133.4	118.2	168.8	66.0	80.2	56.6	77.8	70.1
5.	GMJ3/PK35	120.7	133.0	165.4	108.9	132.0	64.3	52.5	32.0	63.4	53.1
6.	GMJ7/PK37	108.7	197.2	131.1	131.2	142.0	54.9	38.4	28.4	63.2	46.2
7.	GMJ7/PK33	109.0	199.0	157.5	110.5	144.0	98.9	38.1	20.5	104.9	65.6
8.	A7/PK99	111.6	165.3	123.8	124.0	131.2	61.6	33.3	33.8	93.6	55.6
9.	A7/PK35	85.9	161.9	93.3	102.5	110.9	68.1	39.2	21.9	112.2	60.3
10.	A7/PK37	161.0	170.4	73.4	136.9	135.4	74.9	52.9	12.0	78.6	54.6
11.	A7/PK38	123.0	204.9	138.2	110.7	144.2	48.9	42.5	35.8	88.0	53.8
12.	A7/PK36	137.8	201.2	137.4	122.4	149.7	62.3	42.9	30.7	74.0	52.5
13.	A7/PK21	173.5	213.4	198.5	156.2	185.4	74.5	38.5	28.7	71.1	53.2
14.	GMJ3/PK40	123.0	140.3	153.4	112.8	132.4	35.1	38.1	42.3	91.3	51.7
15.	A7/PK40	103.8	302.2	165.9	109.2	170.3	60.9	43.1	21.0	55.6	45.2
16.	GMJ3/PK42	123.5	137.1	95.4	98.5	113.6	47.5	64.7	96.2	59.6	67.0
17.	A7/PK42	146.5	198.9	147.7	110.2	150.8	40.0	42.4	48.7	103.6	58.7
18.	GMJ3/PK43	88.5	141.9	94.8	88.8	103.5	62.0	53.0	99.7	81.9	74.2
19.	GMJ3/PK97	105.2	128.0	104.4	95.1	108.2	51.5	61.1	75.2	90.8	69.7
20.	GMJ3/PK32	109.5	132.7	67.7	106.8	104.2	54.5	64.7	81.2	77.3	69.4
21.	A7/PK32	90.7	167.4	263.8	111.1	158.2	51.0	33.7	46.2	61.9	48.2
22.	GMJ7/PK40	159.4	181.3	141.3	116.4	149.6	40.3	28.7	20.7	78.8	42.1
23.	GMJ6/PK36	125.9	185.7	82.7	150.9	136.3	71.7	67.7	18.1	106.1	65.9
24.	GMJ6/PK38	117.1	171.3	92.7	144.2	131.3	89.3	31.2	18.9	103.4	60.7
25.	Hipa10	125.8	155.9	149.8	110.0	135.4	30.7	23.1	12.5	43.9	27.6
26.	Ciherang	127.3	138.7	159.1	141.4	141.6	72.4	85.5	92.7	78.4	82.2
	Mean	120.8	179.9	135.3	117.3	138.3	60.6	47.3	42.7	80.0	57.6
	Mean (location)		150.3		126.3			53.9		61.4	
	Mean (season)		128.1[a]		148.6[b]			51.7[a]		63.6[b]	
	LSD 5%	30.3	120.9	68.7	38.0	32.9	21.8	25.6	19.9	38.5	14.1
	Cofficient Variation (%)	15.3	41.9	27.9	19.8	30.2	21.2	34.5	29.1	29.7	31.4

Remarks: DS=dry season; WS= wet season; [a] and [b] are mean of the character for dry and rainy season respectively

Table 4. One-thousand grain weight and grain yield of 26 hybrids rice grown in two locations and two seasons, 2012

No.	Genotypes	1000-grain weight (g) at: Batang DS	Batang WS	Sukamandi DS	Sukamandi WS	Mean	Grain yield (t ha^{-1}) at: Batang DS	Batang WS	Sukamandi DS	Sukamandi WS	Mean
1.	GMJ6/PK32	29.6	27.4	26.1	29.5	28.2	6.20	4.46	7.59	4.05	5.58
2.	GMJ7/PK99	28.6	26.4	25.5	29.0	27.4	5.35	4.10	6.71	4.65	5.20
3.	GMJ3/PK39	29.2	29.6	26.4	31.0	29.0	5.43	3.92	6.45	5.21	5.25
4.	GMJ3/PK99	30.6	28.0	26.4	29.6	28.6	4.08	4.05	5.79	4.12	4.51
5.	GMJ3/PK35	28.7	30.6	26.8	29.7	29.0	4.79	3.71	7.24	5.14	5.22
6.	GMJ7/PK37	26.7	25.2	24.9	28.0	26.2	7.01	4.90	8.09	6.84	6.71
7.	GMJ7/PK33	27.9	28.9	25.4	30.1	28.1	6.45	4.35	6.96	5.04	5.70
8.	A7/PK99	28.0	25.5	25.0	28.4	26.7	7.01	4.24	7.93	6.34	6.38
9.	A7/PK35	27.6	28.5	24.5	28.1	27.2	6.89	4.36	8.53	4.23	6.00
10.	A7/PK37	25.6	27.6	24.9	27.8	26.5	6.65	5.98	9.04	7.34	7.25
11.	A7/PK38	27.9	26.1	24.5	27.8	26.6	6.27	6.55	7.62	6.48	6.73
12.	A7/PK36	25.9	26.0	25.0	29.2	26.5	7.56	4.78	8.63	6.47	6.86
13.	A7/PK21	28.4	24.5	24.6	28.2	26.4	6.90	5.27	8.25	7.18	6.90
14.	GMJ3/PK40	30.1	30.6	25.9	30.6	29.3	4.75	4.09	6.40	5.15	5.10
15.	A7/PK40	25.9	27.1	25.1	27.9	26.5	6.95	7.34	8.53	7.85	7.67
16.	GMJ3/PK42	31.0	30.5	26.8	29.6	29.5	4.91	3.20	6.21	5.06	4.84
17.	A7/PK42	26.7	27.4	24.2	28.3	26.6	7.17	4.34	8.27	6.45	6.56
18.	GMJ3/PK43	29.1	29.1	26.8	30.9	29.0	4.28	3.89	5.79	4.70	4.66
19.	GMJ3/PK97	30.1	23.2	25.9	29.4	27.2	4.31	4.30	6.20	4.73	4.89
20.	GMJ3/PK32	29.0	29.4	26.8	29.9	28.8	4.27	3.74	6.05	6.20	5.07
21.	A7/PK32	25.7	25.8	26.5	29.6	26.9	6.09	7.69	8.53	4.68	6.75
22.	GMJ7/PK40	27.9	27.1	24.7	30.9	27.6	6.89	4.18	9.42	7.19	6.92
23.	GMJ6/PK36	27.2	28.6	24.3	27.5	26.9	5.32	4.48	6.01	6.40	5.55
24.	GMJ6/PK38	26.3	27.1	23.3	27.7	26.1	6.92	3.08	6.92	7.57	6.12
25.	Hipa10	27.3	26.8	26.3	28.0	27.1	7.07	4.34	8.08	6.60	6.52
26.	Ciherang	26.7	25.5	25.0	29.3	26.6	6.48	5.09	6.55	9.18	6.82
	Mean	28.0	27.4	25.5	29.1	27.5	6.0	4.6	7.4	6.0	6.0
	Mean (location)	26.7		28.2			6.7		5.3		
	Mean (season)	27.7[a]		27.3[b]			5.3[a]		6.7[b]		
	LSD 5%	1.0	2.1	0.9	2.5	3.1	0.8	1.5	1.2	1.2	0.8
	Cofficient Variation (%)	2.2	4.7	2.2	5.2	14.4	8.3	19.8	12.7	12.7	16.4

Remarks: DS=dry season; WS= wet season; [a] and [b] are mean of the character for dry and rainy season respectively

Table 5. Correlation coefficients among characters in Batang (under the diagonal) and Sukamandi (above the diagonal)

Characters	Grain yield	No. of prod. tillers/plant	Panicle lenght	No. of filled grains/pan.	No. of unfilled grains/pan.	1000-grain weight
Grain yield		0.21 **	-0.17 ns	0.20**	-0.25**	-0.36**
No. of prod. tillers/plant	0.21**		-0.10 ns	-0.02 ns	-0.11 ns	-0.38**
Panicle lenght	0.05 ns	-0.01 ns		-0.18 ns	0.27**	0.26**
No. of filled grains/pan.	0.12 ns	-0.06 ns	0.19**		-0.43**	-0.29**
No. of unfilled grains/pan.	0.07 ns	0.04 ns	0.02 ns	-0.40**		0.41**
1000-grain weight	-0.32**	-0.07 ns	0.01 ns	-0.24**	0.17**	

Remarks: ** = Significant at 1% probability level; ns = Non significant

The data on average yield revealed that only one hybrid produced significantly higher paddy yield than Ciherang (inbreed check and popular variety) and Hipa10 (hybrid check variety), namely A7/PK40 (Table 4). The average yield of hybrids at ranged from 4.5 t ha^{-1} (GMJ3/PK99) to 7.7 t ha^{-1} (A7/PK40). On the average, A7/PK40 produced the highest yield (7.7 t ha^{-1}) compared to all check varieties and the other hybrid rice, followed by A7/PK37 (7.3 t ha^{-1}). The yield advantage of hybrid rice over inbreed or local varieties has already been reported by several researchers (Akram *et al.,* 2007; Satoto *et al.,* 2007; Akhter *et al.,* 2007; Widyastuti and Satoto, 2012).

Correlation and Path Analysis

Grain yield is a complex trait and highly dependent on the other agronomic characters (Hairmansis *et al*., 2010). All possible correlations among the different characters for each location were measured (Table 5). In Batang, grain yield exhibited significantly positive correlation with number of panicles per hill (r=0.21) and also exhibited significantly negative correlation with 1000-grain weight (r=-0.32). Panicle length showed positive correlation with the number of filled grain per panicle (r=0.19). While the number of unfilled grains per panicle had a positive correlation with 1000-grain weight (r=0.17).

In Sukamandi, grain yield also showed significantly positive correlation with the number of panicles per hill (r=0.21) and the number of filled grains per panicle (r=0.20). Panicle length revealed positive correlation with the number of unfilled grains per panicle (r=0.27) and 1000-grain weight (r=0.26). Meanwhile, the number of unfilled grains per panicle had positive correlation with 1000-grain weight (r=0.41). Similarly the result of the study conducted by Akinwale *et al.,* (2011) revealed that the number of panicles per plant, panicle weight and the number of grains per panicle were the most important yield components.

Generally, the study conducted at two locations revealed the same pattern of correlation among different characters. Hence, intensive selection on the positive side number of tillers per plant and number of filled grains per panicle since these characters showed positive correlation with grain yield (Table 5).

Table 6 explains the details of agromomic character effects on grain yield and its relationship with each other in the determination of rice yield. The two locations showed different direct effects of agronomic traits on yield. Batang has Latosol soil type and altitude 276 meters above sea level; the path analysis showed that the number of panicles per hill, panicle length, and the number of unfilled grains per panicle had significant positive direct effect on grain yield. Meanwhile, Sukamandi which has Alluvial soil type and altitude 16 m above sea level; the path analysis result indicated that the number of panicles per hill and the number of filled grains per panicle had significant positive direct effect on grain yield, with correlation value of 0.099 and 0.139 respectively.

Table 6. Direct and indirect of yield-related traits

Characters	Direct and indirect effect					Total Effect
	No. of panicles/hill	**Panicle lenght**	**No. of filled grains/panicle**	**No. of unfilled grains/panicle**	**1000-grain weight**	
Location: Sukamandi						
No. of panicles/hill	**0.099**	0.007	-0.003	0.005	0.107	0.315
Panicle lenght	-0.010	**-0.071**	-0.025	-0.012	-0.075	-0.264
No. of filled grains/panicle	-0.002	0.013	**0.139**	0.020	0.082	0.389
No. of unfilled grains/panicle	-0.011	-0.019	-0.059	**-0.047**	-0.118	-0.300
1000-grain weight	-0.037	-0.019	-0.040	-0.019	**-0.284**	-0.683
Location: Batang						
No. of panicles/hill	**0.194**	-0.001	0.001	0.004	0.021	0.413
Panicle lenght	-0.003	**0.051**	-0.004	0.003	-0.002	0.096
No. of filled grains/panicle	-0.011	0.010	**-0.019**	-0.041	0.070	-0.011
No. of unfilled grains/panicle	0.008	0.001	0.008	**0.102**	-0.051	0.169
1000-grain weight	-0.014	0.000	0.005	0.018	**-0.287**	-0.565

Information on the contribution of each agronomic character to grain yield is very useful for breeders as the indirect selection of grain yield during the early generation before conducting replicated yield trials (Samonte *et al*., 1998). However, this study also showed high residual effect coefficient, namely 0.908 and 0.927, which indicated there were other variables which determined rice grain yield and had not been explained in this experiment. Further studies are required to elucidate the relationship between the grain yield and the other morpho-physiological traits.

CONCLUSION AND SUGGESTIONS

From the research, it is concluded that among F_1 hybrids rice, the identified superior performing hybrids A7/PK37 and A7/PK40 which have good performance for mean yield and its component are also resistant to BLB strain III. Based on correlation and path analysis, the number of panicles per hill and the number of filled grains per panicle could be used as selection criteria for yield in hybrid rice.

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REFERENCES

Akhter, M., M. Sabar, M.A. Zahid and M. Ahamd. 2007. Hybrid rice research and development in Pakistan. Asian J.Plant Sci. 6 (5): 795-801.

Akinwale, M.G., G. Gregorio, F. Nwilene, B.O. Akinyele, S.A. Ogunbayo and A.C. Odiyi. 2011. Heritability and correlation coefficient analysis for yield and its components in rice (*Oryza sativa* L). Afr. J. Plant Sci. 5 (3): 207-212.

Akram, M., A. Rehman, M. Ahmad and A.A. Cheema. 2007. Evaluation of rice hybrids for yield and yield components in three different environments. J. Anim. Pl. Sci. 17 (3-4): 70-74.

Board, J.E., M.S. Kang and B.G. Harville. 1997. Path analysis identify indirect selection criteria for yield of late-planted soybean. Crop Sci. 37 (3): 879-884.

Chen, L., Y. Xiao, W. Tang and D. Lei. 2007. Practices and prospects of super hybrid rice breeding. Rice Sci. 14 (2): 71-77.

Gomez, K.A. and A.A. Gomez. 1985. Statistical procedures for agricultural research. John Willey and Sons, Inc. Canada. pp. 680.

Hairmansis, A., B. Kustianto and Suwarno. 2010. Correlation analysis of agronomic characters and grain yield of rice for tidal swamp areas. Indones. J. Agric. Sci. 11 (1): 11-15.

Kueneman, E.A. 2006. Improved rice production in a changing environment: from concept to practice. Intl. Rice Comm. Newsl. 55: 1-20.

Nugraha, Y., E. Lubis and M. Diredja. 2004. Identification of elite lines of rice (*Oryza sativa* L.) for parental of hybrid rice (in Indonesian). Buletin Plasma Nutfah 10 (1): 12-16.

Nugraha, Y., Y.P. Munarso and Satoto. 2011. Development of new cytoplasmic male sterile rice lines resistant to bacterial leaf blight and brown plant hopper (in Indonesian). J. Penelitian Pertanian Tanaman Pangan. 30 (1): 9-16.

Reddy, M.V., D. Subramanyam, B. Krishnamurty, J.R. Reddy, N.S. Reddy and A.D. Raj. 1986. Variability, heritability, and genetic advance in Virginia cultivars of groundnut (*Arachis hypogaea* L.). Indian J. Genet. Pl. Br. 46 (2): 355-359.

Samonte, S.O.P.B., L.T. Wilson and A.M. Mc Clung. 1998. Path analyses of yield and yield-related traits of fifteen diverse rice genotypes. Crop Sci. 38 (5): 1130-1136.

Satoto, I.A. Rumanti, M. Diredja and B. Suprihatno. 2007. Yield stability of ten hybrid rice combinations derived from introduced CMS and local restorer lines (in Indonesian). J. Penelitian Pertanian Tanaman Pangan. 26 (3): 145-149.

Satoto, M.J. Mejaya, Y. Widyastuti and I. A. Rumanti. 2013. Yield stability and potential of new hybrid rice varieties (in Indonesian). J. Penelitian Pertanian Tanaman Pangan . 32 (2): 67-73.

Singh, R.K. and B.D. Chaudhary. 1979. Biometrical methods in quantitative genetic analysis. Kalyani Publ. New Delhi. pp. 304.

Widyastuti, Y. and Satoto. 2012. Yield stability and adaptability of five promising hybrids rice at Central Java (in Indonesian). J. Penelitian Pertanian Tanaman Pangan. 31(2): 87-92.