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THE ABILITY OF HYBRID AND INBRED RICE TO PRODUCE RATOON IN TIDAL SWAMPLAND

Kemampuan Varietas Padi Hibrida dan Inbrida untuk Menghasilkan Ratun di Lahan Pasang Surut

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ABSTRACT

Tidal swampland in Indonesia is potential for cultivation of inbred and hybrid rice. However, rice cultivation in this land can be done only one time annually. Rice cultivation with ratoon system in this land might increase production from both the main crop and their ratoon. The study aimed to evaluate the ability of hybrid and inbred rice to produce ratoon and their grain yield in the tidal swampland of Central Kalimantan. The experiment was arranged in a randomized block design with 12 rice varieties as treatments, namely six hybrids (Hipa 3, Hipa 4, Hipa 5, Hipa 6, Maro and Rokan) and six inbreds (Batanghari, Ciherang, IR42, Margasari, Mekongga and Sintanur); replicated three times. Cultivation of the main crop followed the recommendation. At harvest, the main crops were cut at 20 cm from the ground and fertilized with 100 kg ha^{-1} urea. The results showed that ratoon crops were emerged at 5–6 days after cutting, with 2–4 leaves per panicle and 5.5–26.0 tillers per clump. Average harvesting age of the ratoon was 69 days. Ratoon yield of the hybrids was better than that of the inbreds; the average was 75.2% of the main crops. Based on the criteria of rice yield, three clusters were identified, i.e. high (>2 t ha^{-1}): Hipa 3, Hipa 4, Hipa 5, Maro, Rokan, Ciherang and Sintanur; medium (1–2 t ha^{-1}): Hipa 6, IR42, Margasari and Mekongga, and low, Batanghari. The study suggests that hybrid varieties could be developed in tidal swamplands.
[**Keywords**: ratooning, ratoon system, rice, tidal swampland]

ABSTRAK

Lahan pasang surut di Indonesia sangat potensial untuk ditanami padi inbrida dan hibrida. Namun, penanaman padi di lahan pasang surut hanya dapat dilakukan setahun sekali. Penelitian bertujuan untuk mengevaluasi kemampuan varietas padi inbrida dan hibrida untuk membetuk ratun serta hasil gabahnya di lahan pasang surut Kalimantan Tengah. Percobaan dirancang secara acak kelompok dengan 12 varietas padi sebagai perlakuan, yaitu enam varietas hibrida (Hipa 3, Hipa 4, Hipa 5, Hipa 6, Maro, dan Rokan) dan enam varietas inbrida (Batanghari, Ciherang, IR42, Margasari, Mekongga, dan Sintanur); diulang tiga kali. Budi daya padi mengikuti rekomendasi. Saat panen, tanaman utama dipotong 20 cm dari permukaan tanah kemudian dipupuk urea 100 kg ha^{-1}. Hasil penelitian menunjukkan bahwa tunas ratun mulai keluar pada 5–6 hari setelah panen, dengan 2–4 daun per malai dan 5,5–26,0 anakan per rumpun. Rata-rata waktu panen tanaman ratun 69 hari setelah panen tanaman utama. Hasil gabah ratun padi hibrida lebih tinggi dibandingkan dengan varietas inbrida dengan hasil rata-rata 75,2% terhadap tanaman utama. Berdasarkan kriteria hasil gabah, 12 varietas dapat dikelompokkan menjadi tiga, yaitu potensi hasil tinggi (>2 t ha^{-1}) yakni Hipa 3, Hipa 4, Hipa 5, Maro, Rokan, Ciherang, dan Sintanur); potensi hasil medium (1–2 t ha^{-1}) meliputi Hipa 6, IR42, Margasari, dan Mekongga, serta potensi rendah (<1 t ha^{-1}) yaitu Batanghari. Penelitian mengindikasikan bahwa padi hibrida cocok dikembangkan di lahan pasang surut.

[**Kata kunci**: kemampuan ratun, padi, lahan pasang surut, sistem ratun]

INTRODUCTION

Ratooning is the ability of plant to regenerate new tillers from stubbles of the main crop. Ratooning of rice have been practiced in various countries, such as China, USA, India, Thailand, Phillippines and Japan (Nakano and Morita 2007). The high grain yields of the main crop and ratoon showed that this cultivation technology has a great prospect for tropical hill agriculture (Faruq et al. 2014).

In Indonesia, study on ratooning of rice had been conducted by Susilawati and Purwoko (2011) in the tidal swampland. They found that application of ratoon system increased rice yield 2–3 times of cropping index than the normal un-ratooning. A field experiment of ratooning of inbreed rice variety (Cimelati) and the hybrids (Rokan, Hipa 5, IPB106-7-47-DJ-1 and IPB106-F-8-1) showed that cutting rice plants at harvest at the height of 10–20 cm from the ground produced an additional grains of 1,5–3,0 t ha^{-1} (Susilawati et al. 2012). The grain yield of the ratoon crop was affected by varieties, sowing time, cultivation method, fertilizer rate and stubble height of the main crop (Liu et al. 2015). The main crop at 10 cm height increased grain yield from the ratoon by 2236.3 kg ha^{-1} (Petroudi et al. 2011). Ratoon system of rice, therefore, will benefit to farmers, especialy in tidal swampland, where rice is grown ones a year. For hybrid rice, the benefits of rice ratooning extend to not only shortening the period for crop maturity but also saving various resources such as water, labour, seed and top soil as well as their associated costs owing to the omissible sowing and land preparation and the shortened period for growing (Yamaoka et al., 2017).

Ratooning does not require additional new seeds, which are limited and must be bought from the seed supplyer (Susilawati et al. 2012; Suprihatno et al. 1994). Ratooning, therefore, could increase rice production in tidal swampland from the additional yield.

The additional yield of ratoon crop has been reported by several researchers. Nair and Rosamma (2002) and Santos et al. (2003) reported that the additional rice yield might be up to 66% of the main crop per growing season. Krishnamurthy (1988) stated that the yield of ratoon crop in India and the Phillipines reached 0.7–5.8 t.ha^{-1} depending on the variety used. The ratoon yield of Milbuen 5 rice variety was 5.6 t.ha^{-1} which was higher than that of Tillak Kachari (5.0 t.ha^{-1}), Achra 108/1 (4.8 t.ha^{-1}), IR42 (2.9 t.ha^{-1}) and IR28 (2.1 t.ha^{-1}). In Yujiang County in South East China, the yield of rice ratoon of Eryouhang II variety was 4.0 t.ha^{-1} (Chen et al. 2007). Previous study by Susilawati and Purwoko (2012) showed that amongst five inbreed rice varieties, ratooning yield of Batang Samo was higher than that of IR42, Batanghari, Ciherang and Intani-2.

The study aimed to evaluate the ability of hybrid and inbred rice varieties to produce ratoon and their yield in the tidal swampland of Central Kalimantan.

MATERIALS AND METHODS

Experimental Site and Design

The experiment was conducted in Petak Batuah Village at Dadahup Subdistrict of Kapuas Regency from October 2013 to April 2014. The field was a representative of tidal swampland with flooding type B, that is an area flooded by large tides, while in small pairs the water cannot over flowing into the field (Ar-Rhiza and Alkusumah 2008).

The experiment was arranged in a randomized block design with three replications. The treatments included 12 rice varieties, consisted of six hybrids (Hipa 3, Hipa 4, Hipa 5, Hipa 6, Maro and Rokan) and six inbreed rice (Mekongga, Margasari, Ciherang, IR42, Sintanur and Batanghari). Seeds of the varieties were obtained from the Indonesian Center for Rice Research in Subang, West Java. The plot size was 4 m x 5 m. All the plots were subjected under a submerged condition, i.e. the water depth was about 5 cm before planting.

Cutivation of Main Crop

Rice seeds were seeded on seed beds of 1 m x 5 m located at the higher land, and the seedlings were managed following the standard cultivation practices. The land was prepared using a hand tractor and applied dolomite at 1,000 kg ha^{-1} to increase the soil pH. Fifteen day-old seedlings were trasplanted on the prepared land and then fertilized with 150 kg ha^{-1} urea, 100 kg ha^{-1} super phosphate (SP-36) and 150 kg ha^{-1} potassium chloride (KCl) based on the soil analyses recommendation. The full dosage of P, 30% of the total K and 20% of the total N were spread over at the early tillering stage, i.e. at 5 and 6 leaf rice growing period or about 7 days after transplanting (DAT). Then 30% of the total N was applied at booting stage (12 and 13 leaf period or 30 DAT), whereas 20% of the total N and 35% of the total K were applied at 14 and 15 leaf period. Finally, 20% of the total N and 35% of the total K were given at 40 DAT. The main crop was harvested when 80% of the grains on the panicles showed yellowing color (physiologically matured).

Ratoon Crop

Ratooning was conducted after the main crop was harvested by cutting the crops at 10 cm above the soil surface. Following the cutting, the ratoon crops were inundated with water at a level of 5 cm height above the ground (Susilawati et al. 2012). Two days after cutting, the ratoon crops were fertilized with a half dose of the main crop, i.e. 75 kg ha^{-1} urea, 50 kg ha^{-1} SP-36 and 75 kg ha^{-1} KCl.

Plant Sampling and Measurements

The vegetative and reproductive characterictics of the main and ratoon crops were assessed from ten crops of each plot. The parameters observed included plant height, number of productive tillers, panicle length, filled grain, empty grain, flowering age, day of maturity, 1000 grain weight and grain yield.

Ratooning Ability

Ratooning abilities of the tested crops were grouped into three category, high, medium and low, based on

Table 1. Criteria of the potential yield of ratoon crop.

Criteria	Relative yield	Real yield
High	> 50% of main crop	> 2 t ha^{-1} or > 12.5 g/panicle
Medium	30-49% of main crop	1-2 t ha^{-1} or 6.25-12.5 g/panicle
Low	10-29% of main crop	< 1 t ha^{-1} atau < 6.5 g/panicle

Source : Susilawati (2011)

the relative and real yields. The relative yield was the ratio between the seed weight per clump of the ratoon to the main crops. The real ratoon yield was calculated from the amount of the real production obtained from the ratoon plants on the main crops (Tabel 1) (Susilawati 2011).

Data Analysis

The agronomic data were subjected for the analysis of variance (ANOVA) using SAS 9.0 software (SAS 2010). The least significant different at P = 0.05 was used for comparing the varietal performance. The ratooning ability of each variety was classified as high, medium and low based on the relative and real yields (Susilawati 2011) (Table 1).

RESULTS AND DISCUSSION

Vegetative Growth

The vegetative characteristics of the six hybrid rice (Hipa 3, Hipa 4, Hipa 5, Hipa 6, Maro and Rokan) were not significantly different, whereas, those of the two inbred varieties (Mekongga and Batanghari) were significantly different from the other inbreeds (Ciherang, IR42, Margasari and Sintanur) for their plant height and number of productive tillers (Table 2). This result shows that hybrid varieties have a good adaptability to environmental conditions with low pH. Virmani and Kumar (2004) explained that hybrid rice is expanding faster in areas of moderate stress possibly because of the homeostasis effect. In rice plants, the homeostasis effects are primarily to increase the role of steroid hormones which modulate various physiological processes, such as increasing and decreasing Fe concentration in the roots and shoots, respectively (Wang et al. 2015). Thus it can be assumed that hybrid rice will be better to maximize nutrient translocation which is closely related to ratoon yield ability, especially in tidal land that have high Fe.

In general, plant height and number of productive tillers of main crops were higher than their respective ratoons, both for the hybrid and inbreed varieties (Table 2). This condition may be due to the differences in total assimilates in the stubbles after harvesting the main crop. Stubble of rice plants that grow back after harvest and produce new tillers and grain which can be harvested (Islam et al., 2008; E Mareza et al. 2016).

High assimilates in stubble cause the stubble still vigor, then the ratoon emerged. Otherwise if assimilate stored in stubble was low, seedling growth will be delayed and needs additional nutrients for growing ratoon. Islam et al. (2008) mentioned that fertilizer applied on main crop and ratoon could supply nutrients for ratoon growth. Dobermann and Fairhust (2000) reported, N fertilizer could stimulate vegetative growth, especially plant height and number of productive tillers. Xueyong et al. (2003) stated that number of productive tillers is an important agronomic character for grain production. Yang et al. (1999) mentioned that hybrid rice absorbed total N higher than the inbreds. Approximately 15–20% of the total N was accumulated in the hybrid varieties, while the inbred varieties only absorbed 6–7% of the total N accumulated in plants. The hybrid and inbred rice studied were classified as early maturing varieties. The harvesting age ranged between 104.3 and 110.3 days and it was not significantly different among varieties. Harvesting age of the ratoon was shorter than that of the main crop, and ratoon of the hybrids had a shorter harvesting age than that of the inbreds, and significantly different among varieties (Table 2).

Reproductive Growth

The generative or reproductive stage of the six hybrids showed that the panicle length and total grain number of main crop were not significantly different, but it was significantly different for the inbred varieties. Sintanur has the longer panicle compared with Mekongga. Total grains and filled grains of the hybrids were higher than that of the inbreds, and not significantly different both for main crops and the ratoon (Table 3).

Ratoon of the hybrid variety Rokan produced the highest total grains and filled grains, namely 203 total grains and 193 filled grains, equivalent with the filled grains of main crop Hipa 6, and higher than main crop itself. Hipa 6 was significantly different with Maro for 1000 filled grain weight and grain yield of ratoon crop. No ratoon was produced by Batanghari because the plant stubbles dried quickly after harvesting the main crop (Table 3). These results are related to the amount of assimilates translocated to the seed that determines the number of filled grains. According to Ai-Zhong et al. (2007), 65–80% of photosynthesis

Table 2. Agronomic characters of ratoon and main crop for hybrid and inbred rice varieties at vegetative phase, October 2013–April 2014.

Varietal group	Varieties	Plant height (cm)		Productive tiller number (tiller)		Flowering age (AF) (days)		Harvesting age (AH) (days)		AH - AF (days)	
Ratoon											
Hybrid	Hipa 3	92.0	ab	11.7	bcd	18.7	ab	18.0	a	69.0	de
	Hipa 4	85.0	abc	26.0	a	19.7	ab	18.0	a	68.0	ef
	Hipa 5	74.7	abc	19.7	ab	20.3	ab	15.7	a	67.0	f
	Hipa 6	64.7	c	6.7	d	14.0	b	20.0	a	70.0	cd
	Maro	95.3	ab	18.7	abc	19.3	ab	18.0	a	62.0	h
	Rokan	89.0	abc	15.7	bcd	22.7	a	21.0	a	63.0	h
Inbred	Batanghari	-		-		-		-		-	
	Ciherang	52.5	c	6.0	d	18.5	ab	18.0	a	70.5	c
	IR42	70.5	abc	5.5	d	15.5	b	15.5	a	76.5	b
	Margasari	105.3	a	9.0	cd	25.0	a	19.0	a	89.0	a
	Mekongga	76.0	abc	13.3	bcd	22.3	a	19.0	a	70.0	cd
	Sintanur	74.0	abc	6.5	d	14.5	b	20.0	a	64.5	g
Main crops											
Hybrid	Hipa 3	128.0	ab	24.7	ab	30.0	a	82.2	b	104.0	b
	Hipa 4	133.0	ab	33.7	a	28.0	ab	80.0	bc	105.3	b
	Hipa 5	128.7	ab	27.3	ab	28.2	ab	78.7	bc	106.3	ab
	Hipa 6	135.3	ab	30.0	ab	29.9	a	83.3	ab	105.0	b
	Maro	125.7	ab	29.3	ab	30.3	a	81.0	b	106.3	ab
	Rokan	140.0	a	32.7	a	30.1	a	82.0	b	106.0	ab
Inbred	Batanghari	127.3	ab	32.3	a	25.7	ab	73.7	c	106.0	ab
	Ciherang	119.0	bc	25.7	ab	27.4	ab	81.3	b	104.7	b
	IR42	141.7	a	27.0	ab	26.5	ab	81.3	b	110.3	a
	Margasari	126.0	ab	21.7	ab	26.2	ab	84.3	ab	105.0	b
	Mekongga	108.3	c	16.7	b	24.5	b	80.7	b	103.0	b
	Sintanur	127.0	ab	21.0	ab	30.7	a	89.0	a	104.3	b

AF = Age of flowering, AH = Age of harvester.
Different letters within a column are significantly different from each other at the DMRT 0.05 level.

yield were distributed to the second and third segments of ratoon, which correlated positively with yield and yield components of ratoon. Nakano et al. (1997) also reported that physiologically hybrid rice have large source and sinks, strong root system and high biomass, so the carbohydrate content that can be utilized is high.

Flowering age of the main crop on hybrid and inbred varieties ranged between 73.7 and 89.0 days and not significantly different among varieties, except Batanghari which had the shortest flowering time of 73.7 days. Similarly, the day of ratoon flowering was not significantly different, both for hybrid and inbred varieties. Day of flowering of ratoon was faster than this at the main crop, i.e. 15.5–21.0 days after main crop harvest. For ratoon, flowers and leaves appeared simultaneously, especially for plants with higher cutting height which reached 50% flowering age shortly. This condition was associated with growth phase of ratoon which does not pass through the vegetative stage (Vergara 1995).

Yield

The average difference between flowering and harvesting age was 24 days for main crops and 47 days for ratoon. The growing pattern of rice plants from seeds passes three phases, one of them is the maturation phase, that is a phase of rice growth starting from flowering until harvest. The phase generally took 30 days and was relative similar for each variety (Vergara 1995). This condition occurred in main crop with 6 days difference but was not significantly different. In ratoon, varieties result in at least two leaves per tiller of ratoon. All rice varieties tested were capable of producing ratoon, i.e. Hipa 3, Hipa 4, Hipa 5, Hipa 6, Maro, Rokan, Mekongga and Margasari. Three varieties had a medium potential yield of ratoon, i.e. Ciherang, IR42 and Sintanur and one

Table 3. Agronomic characters of ratoon and main crop of hybrid rice and inbred varieties at repoductive stage, October 2013–April 2014.

Group	Varieties	Panicle length (cm)		Total grain (seed)		Filled grain per panicle (seed)		(%) Total empty grain		Weigh of 1000 filled grains (g)		Yield (g)	
Ratoon													
Hybrid	Hipa 3	18.7	ab	113.0	ab	65.3	b	42.2	ab	17.7	b	13.5	de
	Hipa 4	19.7	ab	140.3	ab	124.7	ab	11.2	b	16.4	c	53.1	a
	Hipa 5	20.3	ab	176.0	ab	141.3	ab	19.7	ab	16.2	cd	45.0	ab
	Hipa 6	14.0	b	75.3	b	62.0	b	17.7	b	15.7	d	6.5	e
	Maro	19.3	ab	98.0	ab	87.7	ab	10.5	b	17.4	b	28.5	cd
	Rokan	22.7	a	203.0	a	193.0	a	4.9	b	15.0	e	45.2	ab
Inbred	Batanghari	-		-		-		-					
	Ciherang	18.5	ab	209.0	a	108.0	ab	48.3	a	17.3	b	31.3	bc
	IR42	15.5	b	147.5	ab	99.0	ab	32.9	ab	18.7	a	9.8	e
	Margasari	25.0	a	173.3	ab	101.7	ab	41.3	ab	13.7	f	12.6	de
	Mekongga	22.3	a	97.7	ab	44.3	b	54.6	ab	16.2	cd	9.6	e
	Sintanur	14.5	b	206.5	a	138.5	ab	32.9	ab	16.2	cd	28.2	cd
Main crops													
Hybrid	Hipa 3	30.0	a	256.3	abcd	163.3	ab	36.4	abcd	22.0	abc	60.1	a
	Hipa 4	28.0	ab	253.7	abcd	165.3	ab	47.6	ab	20.2	bc	35.0	a
	Hipa 5	28.2	ab	289.7	ab	155.0	ab	46.5	a	21.8	abc	59.3	a
	Hipa 6	29.9	a	314.0	a	193.3	a	38.4	ab	20.5	bc	25.8	a
	Maro	30.3	a	264.7	abc	158.7	ab	40.1	abc	20.3	bc	37.1	a
	Rokan	30.1	a	234.7	abcd	132.0	abc	43.9	abcd	22.4	abc	45.5	a
Inbred	Batanghari	25.7	ab	187.0	bcde	92.0	bc	50.8	abcd	21.3	abc	23.1	a
	Ciherang	27.4	ab	106.7	e	53.8	c	49.7	de	22.6	ab	33.2	a
	IR42	26.5	ab	194.7	bcde	112.3	abc	42.5	cde	18.9	c	41.3	a
	Margasari	26.2	ab	177.3	bcde	114.3	abc	19.4	e	20.3	bc	31.7	a
	Mekongga	24.5	b	152.0	cde	93.2	bc	38.6	cde	20.4	bc	20.4	a
	Sintanur	30.7	a	147.3	de	113.3	abc	23.3	e	24.1	a	32.8	a

Different letters within a column are significantly different from each other at the DMRT 0.05 level.

Table 4. Comparation of the yield of main crop and ratoon of hybrid and inbred rice varieties in the swampland of Central Kalimantan based on grain weight per hill.

Group	Variety	Main crop yield (g)	Ratoon crop yield (g)	% ratoon to main crop yield	Criteria of yield	
					Relative	Real
Hybrid	Hipa 3	60.10	13.50	22.46	L	H
	Hipa 4	35.00	53.10	151.71	H	H
	Hipa 5	59.30	45.00	75.89	H	H
	Hipa 6	25.80	6.50	25.19	L	M
	Maro	37.10	28.50	76.82	H	H
	Rokan	45.50	45.20	99.34	H	H
Inbred	Batanghari	23.10	0.00	0.00	L	L
	Ciherang	33.20	31.30	94.28	H	H
	IR42	41.30	9.80	23.73	L	M
	Margasari	31.70	12.60	39.75	M	M
	Mekongga	20.40	9.60	47.06	M	M
	Sintanur	32.80	28.20	85.98	H	H

H = high; M = medium ; L = low.

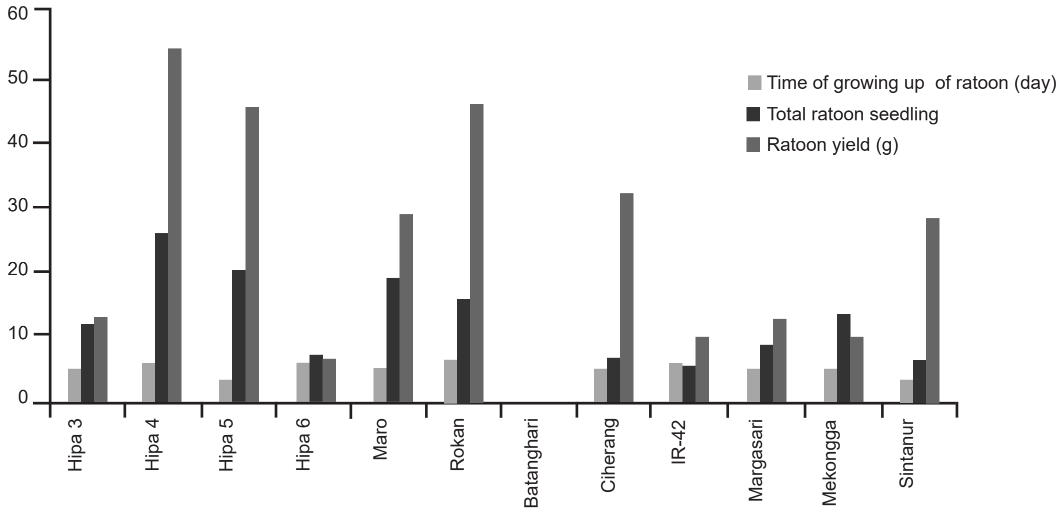

Fig. 1. Time growing up of ratoon, total raton seedling and ratoon yield.

variety had a low potential yield of ratoon. Batanghari produced less ratoon and some of the emerging tillers died. Although the ratoon died, in the analysis based on the character of the yield from the main crop and ratoon entered.

Based on the real criteria of rice yield, the varieties were grouped into three clusters, i.e. high, medium and low potentials (Table 4). Seven varieties had a high potential yield (>2 t ha^{-1}), i.e. Hipa 3, Hipa 4, Hipa 5, Maro, Rokan, Ciherang and Sintanur; four varieties had a medium potential yield (1–2 t ha^{-1}), i.e. Hipa 6, IR42, Margasari and Mekongga; and Batanghari showed the lowest potential yield (<1 t ha^{-1}).

Time required by stubbles for emerging ratoon of the hybrid and inbred rice was the same, ranging from 5 to 6 days after harvest, with 2–4 leaves per tiller. Regenerated rice tillers were developed from nodal buds on the remaining stubble after harvesting the main crop. In ratoon season, one tiller can regenerate more than one panicles (Dong et al. 2017). Number of ratoons per tiller also varied (Figure 1). Some varieties produced high number of ratoons per tiller so the ratoons tend to be smaller, have a shorter panicle and smaller seed than that with low ratoon number. The 1000 grain weight and grain weight per hill of ratoon was not significantly different for Hipa 4 and Hipa 5. Seedling number of Hipa 5 was less than Hipa 4, but the 1000 grain weight and the grain yield were not significantly different.

Genetically, hybrid rice have better vigor than their parents (Satoto et al. 2009). The hybrid rice is being the new answer to the growing world population; by the way of its elevated yield potential, agronomic performance and disease resistance (Hasan et al. 2011). This indicates that development of hybrid rice with ratoon system is not only able to increase rice production by twice harvest per season, but also reduce seed needed for twice planting. In addition, stubbles of the hybrid rice are staying green after harvesting the main crop (McCauley et al. 2006).

Temperature is an environmental factor that affects ratooning ability of the main crops. During the study, the temperature reached 29 °C. The appropriate temperature for ratooning growth was 21–29 °C. High temperatures during flowering may disrupt pollen development and reduce yield significantly, and thought to cause cenecence and drying of crops after harvest (Chauhan et al. 1989).

CONCLUSION

The potential yield of main crop and ratoon of hybrid and inbred rice in tidal swamplands of Central Kalimantan had been identified. The hybrid varieties produced higher yield than the inbred ones, with an average of 75.2% of the main crop. Based on the real criteria of rice yield, the varieties were clustered into high potential (>2 t ha^{-1}): Hipa 3, Hipa 4, Hipa 5, Maro, Rokan, Ciherang and Sintanur); medium (1–2 t ha^{-1}): Hipa 6, IR42, Margasari and Mekongga, and low (Batanghari). The study suggests that hybrid rice have a high potential in increasing rice yield from both the main crops and their ratoon, therefore, they could be developed in tidal swamplands of Central Kalimantan.

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