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Screening of Rice Genotypes and Evaluation of their Ratooning Ability in Tidal Swamp Area

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ABSTRACT

Indonesia has a large diversity of local tidal swamp rice with ratooning character that can be exploited. The study was aimed to screen 68 of rice genotypes that have ratoon traits from 68 genotypes, to determine the selection criteria for ratoon rice and to determine the performance of selected genotypes in tidal land. The experiment was designed in a Randomized Complete Block Design (RCBD) with three replicates. Each genotype was planted in four rows of 5 m long with spacing of 20×20 cm with 20 days old seedling. Each hill was planted with one seedling. Plants were harvested 32 days after heading by cutting at a height of 10 cm from the soil surface. One day after harvest, the land was irrigated as high as 3 cm and sown Urea 50 kg ha^{-1}, TSP 30 kg ha^{-1} and KCl 25 kg ha^{-1}. Of the 68 genotypes tested, the highest nine at ratoon genotypes were tested in tidal acid sulphate soil in a RCBD with three replicates. The results showed that there was a variation of ratooning ability among genotypes tested with regard to yield of ratoon. Culm diameter of main crop had highest significant direct effect to yield of ratoon. Genotypes of IPB97-F-13-1-1, IPB107-F-14-4-1, IPB107-F-14-5-1, IPB Batola 6R, Inpago IPB 8G, IPB 4S, IPB BATOLA 5R, IPB 3S and IPB107-F-18 were able to produce at least 7.5 g/hill of Dry Milled Grain (DMG). The ratoon of these genotypes produced the yield of at least 40% from the main crop, showed good performance and possessed similar harvesting period. Further, the ratoons of IPB97-F-13-1-1, IPB107-F-14-4-1, IPB 4S and IPB 3S produced 1.55, 1.60, 1.53 and 1.53 t ha^{-1} of DMG in the acid sulfate soil, respectively. It can be concluded that genotype with ratooning ability were valuable to increase rice production in tidal land.

Key words: Ratoon, tiller, culm, main crop, yield

INTRODUCTION

Tidal land could become the foundation of future food security in Indonesia, specifically for rice farming because it is still widely available with a total of 20.1 million hectares (LWCADIC, 2014). Increasing rice productivity in this area will greatly affect the food security and national economies. However, efforts to increase the production within the area of tidal land are still difficult due to the natural problems, farmers social and cultural and the fanaticism of farmers to local cultivars. Flooding after harvest season in wetlands (Adigbo *et al.*, 2012) or drought causes the soil to become uncultivatable. So, it is quite difficult to increase Cropping Intencity (CI) from once an year to more than once an year. One way to increase rice production in areas which are difficult in adopting CI and new varieties is ratooning system using new plant type rice ratoon which have similarities with local cultivars commonly grown by the farmers. Ratoon is an appropriate technology with low input and has potential to increase rice production in tidal areas (Adigbo *et al*., 2012), to improve the resilience of farmers to climate change (FAO, 2014), to produce more rice in a narrow area, limited water and low cost (Pinera and Martin, 2011). In general, rice farmers in tidal wetlands were familiar to the term of ratoon. Ratoons are plants grow from buds contained in the node stubble or rice stalks left at harvest (Harrell *et al*., 2009). However, not many farmers use it as a source of income because yield of ratoon is usually low. Through the introduction of the new ratooning varieties with grain quality similar to the local cultivars, the effort to increase production will be much easier.

Crosses of local varieties to improve ratooning trait have been implemented and the lines still need to be tested for their ratooning ability. Susilawati *et al*. (2012) reported that the yield of 5 ratoon rice genotypes tested in the tidal area ranged from 38.1-56.6% of the main crop yield.

Some characters like: Fast growth and vigor, culm thickness, early maturity and stay green leaves may correlate with the characters of ratoon and controlled genetically but the most dominant factor influencing yield of ratoon is unknown. Culm thickness correlated with high levels of carbohydrates in the culm. Carbohydrates reserve can induce ratoon regeneration ability better, produces more ratoon tiller and higher grain yield (Palchamy and Purushothaman, 1988; Ichii and Ogaya, 1985). There was variation in the ratooning ability between cultivars as a result of genetic control (Bahar and De Datta, 1977) and environmental influences.

New plant type rice has better vegetative growth and has yield ratoon higher than other varieties but hybrid varieties have better vigor than inbreed (Susilawati *et al*., 2010). Out of the 30 varieties/lines tested for their ratooning ability, only 3 lines which have the potential ratoon in terms of plant vigor (Oad and Cruz, 2002). Duration of growth is one of the genetic trait that have significant effect on the ratooning ability and yields (Vergara *et al*., 1988).

Differences of varieties are also associated with the origin of ratoon tillers emergence on rice straw. Tillers can emerge from all the node on the trunk or from lower node or from a certain number of nodes. Many findings indicated that ratoon crop would produce better yield if the main crop culm is cut by leaving 2-3 nodes. Variations in soil, water, light and temperature greatly affect the ratooning ability (Krishnamurthy, 1989). Physiological aspects such as the rate of net photosynthesis at different phases of grain filling among cultivars, causing yields of ratoon different from each other (Zhang *et al*., 2011). Therefore, selection in the ratoon genotypes might obtain good ratoon ideotype.

On the other hand, the ratooning ability of varieties greatly influenced by cultivation techniques. Liu *et al*. (2012) found transplanting system, generates better ratoon than seeding system or direct seeding. Unfortunately, to date, information about screening of rice genotypes that able to produce ratoon in tidal land is still very limited. Therefore, the objective of the present study was to investigate the ratooning variability on various genotypes of rice, to develop selection criteria for ratoon characteristics that correlate with ratooning ability and to determine the potential yield of ratoon in tidal land. Selection was directed towards rice genotypes possessing high ratoon productivity.

MATERIALS AND METHODS

Screening genotype: There were 68 rice genotypes tested, 16 local varieties: Siam Linggis, Siam Mutiara, Brenti, Siam Unus, Siam Kuning, Beras Merah, Siam Narsis, Siam Jerurut, Karya

Pelalawan, Cekau F10, Cekau F14, Cekau F32, Cekau F33, Cekau F37, Cekau A, Korea N; 2 hybrid varieties: Hipa 8 and Hipa 10; 39 inbred lines: IPB97-F-13-1-1, IPB107-F-95, IPB107-F-14-4-1, IPB107-F-14-5-1, IPB107-F-18-4-DJ-1, IPB Batola 6R, Inpago IPB 8G, IPB 4S, IPB107-F-7-3-1, IPB107-F-13-1, IPB107-F-40E-1, IPB107F-5-5-1, IPB107-F-20-5-1, IPB107-F-34-1, IPB107-F-77-3, IPB107-F-10-1, IPB BATOLA 5R, IPB117-F-14-2-1, IPB105-F-20-1, IPB 3S, IPB107-F-60-1, IPB107-F-18-4-1, IPB107-F-18, IPB107-F-16-5, IPB107-F-127, IPB107-F-135, IR 09F164, IR 09F159, HHZ5-SAL10-DT2-DT1, IR 09F229, IR 09F250, IR 09F496, HHZ5-SAL10-DT1-DT1, IR 09F504, IRRI 119, IPB107-F-65-3-1, PSBRC 82 Sub1, BP1031F-PN-25-2-4-KN-2, Ciherang Sub1; 10 inbred varieties: IPB 1R Dadahup; Margasari; IPB 2R Bakumpai; Inpara 1; Inpara 2; Inpara 3; Gilirang; Cimelati; Ciapus; Inpari 2; and 1 new plant type: Fatmawati. Genetic materials were obtained from the Bogor Agricultural University, Indonesian Center for Rice Research, Local Kalimantan and Local Riau.

Screening of rice genotypes was conducted in Bogor, West Java Province from October 2011 to May 2012. Genotypes were planted using a randomized complete block design with three replicates each. The genotypes were planted four rows in 5 m with spacing of 20×20 cm when seedlings were 20 days old. Each hill was planted with one seedling.

Basic fertilizer based on result of soil analysis were Urea 100 kg ha^{-1}, TSP 150 kg ha^{-1} and KCl 50 kg ha^{-1}, given in conjunction with Furadan® 3G 16 kg ha^{-1} one day before transplanting. Supplementary fertilizer of Urea 50 kg ha^{-1} based on leaf color chart and KCl 50 kg ha^{-1} were given at 35 Days After Transplanting (DAT). Control of pests and diseases is done in an integrated manner. Plants protected by trap barrier system to deter rats and experimental area covered with bird nets.

Harvesting is done after 95% panicle ripening by cutting at a height of 10 cm from the soil surface (Petroudi *et al*., 2011). One day after harvest, irrigated land as high as 3 cm and sown Urea 50 kg ha^{-1}, TSP 30 kg ha^{-1} and KCl 25 kg ha^{-1}. Maintenance of ratoon plants was similar to those conducted for main crop.

Of the 68 genotypes tested, selection was made for genotypes that have good ratoon production and one for worst ratoon genotypes. Selection is done as well against some of the characters are correlated with ratooning ability. The plant performance observed by scale categories modified from IRRI (1988): 1 = Very poor, 2 = Poor, 3 = Somewhat good, 4 = Good and 5 = Very good. Harvest uniformity observed using categories: 5 = Uniform, 3 = Somewhat uniform and 1 = Not uniform.

Evaluation of ratooning ability: Selected genotypes were tested in the tidal acid sulphate soil area with type B of flood water in Pulang Pisau District of Central Kalimantan Province from December 2012 to May 2013. The experiment was designed according to randomized complete block design with three replicates. Irrigation system follows the pattern of the ebb and flow of the water in the river, the water was allowed in and out naturally, except at the time of fertilization, water was held in the paddy fields for 7 days.

Statistical analysis: Data was analyzed using ANOVA random model for one season in one location. Genetic variability of observed characters was calculated by Anderson and Bancroft (1952) with the equation:

$$\sigma\sigma_G^2 = \sqrt{\frac{2}{r^2}\left\{\frac{MS_G^2}{db_G + 2} + \frac{MS_g^2}{db_e + 2}\right\}}$$

Genetic variability is broad when $\sigma^2_G \geq 2(\sigma_G)$ and narrow when $\sigma^2_G < 2(\sigma_G)$. The relationship between growth and yield variables were observed, calculated using Pearson correlation analysis. The amount of direct and indirect influence of these variables on the yield of ratoon calculated using path analysis according to Singh and Choudhary (1979). The best genotype in screening determined by highest index value with equation:

$$\text{Index} = W_1X_1+W_2X_2+W_3X_3+\ldots +W_nX_n$$

W = Direct effect value of main crop character to the yield of ratoon
X = Mean value of main crop character

The data of evaluation of ratoon genotype on tidal land was analyzed by analysis of variance followed by Duncan Multiple Range Test. Genotypes that produce high yield ratoon chosen as type ratoon specific for tidal land.

RESULTS

Variability of agronomic characters: The main crop characters and yield of ratoon were observed, have a broad phenotypic variability except the culm thickness. Character, leaf color, culm diameter, number of effective tillers, number of tillers 30 Days After Transplanting (DAT) and clump weights 30 DAT has a narrow genetic variability (Table 1). Phenotype and genetic variability character of main crop productivity, plant height 30 DAT and the number of effective tillers were broad.

Performance of main crops: Out of the 68 genotypes tested, 17 genotypes were found to be high yielding (Table 2). The highest yield of main crop was obtained from HIPA 10 equivalent 5.88 t ha^{-1} grain yield but from the overall appearance of the plant, genotype HIPA 10 was not the best because the leaves of HIPA 10 have been attacked by brown spots diseases and the culm diameter was small so the plant looks weak. This type of growth will produce vulnerable ratoon to disease and weak.. The out of the 17 genotypes only IPB107-F-14-4-1, IPB107-F-14-5-1 and IPB Batola 6R gave high yield and showed good performance. Genotype Inpago IPB 8G was lower than the 17 genotypes but showed a very good performance for stay green leaves which may be important for ratoon. Based on the productivity of main crops there were three genotypes which showed high productivity i.d. HIPA 8, IPB107-F-18 and IPB107-F-65-3-1 with productivity 24.25, 24.06 and 23.96 g per clump grain yield, respectively.

Table 1: Phenotypic varians, genetic variability and heritability characters of 68 rice genotype

Variables	σ^2_P	σ^2_g	Sd	Genetic variability	h^2_{bs} (%)
Main crop productivity	16.6413	15.08737	3.88425	Broad	90.66
Leaf color	1.0154	0.95726	0.97840	Narrow	94.27
Culm diameter	0.0023	0.00209	0.04575	Narrow	89.40
Culm thickness	0.0001	0.00010	0.01006	Narrow	92.19
Plant height 30 DAT	54.5372	48.79101	6.98506	Broad	89.46
Number of effective tillers	2.4703	1.61269	1.26992	Broad	65.28
Clump weights age 30 DAT	1.2326	0.80229	0.89571	Narrow	65.09
Ratoon productivity	10.4259	9.56567	3.09284	Broad	91.75

Table 2: Main crops performance of best 17 rice genotypes selected based on the grain productivity of main crops in the screening of 68 genotypes, Bogor 2012

Genotype	Productivity (g clump^{-1})	Leaf color at harvest	Culm diameter (cm)	Plant height 30 DAT (cm)	No. of effective tiller	No. of tiller at 30 DAT	Clump weight 30 DAT (g)
IPB107-F-14-4-1	23.50^{ab}	4.3^{abc}	0.63^{a}	75.33^{abc}	10.11^{a-j}	12.33^{cde}	6.83^{a}
IPB107-F-14-5-1	21.81^{abcd}	4.7^{ab}	0.56^{c-g}	69.33^{b-l}	8.89^{c-m}	10.97^{de}	4.63^{a-k}
IPB107-F-18-4-DJ-1	20.04^{a-h}	1.0^{K}	0.53^{e-m}	69.67^{b-k}	9.23^{b-m}	12.00^{cde}	5.38^{a-f}
IPB Batola 6R	20.11^{a-h}	2.3^{ghi}	0.60^{abc}	71.33^{a-h}	9.44^{b-m}	10.67^{de}	6.17^{abcd}
IPB107-F-13-1	23.40^{ab}	1.7^{Ijk}	0.55^{c-i}	69.67^{b-k}	8.22^{c-m}	9.03^{e}	5.06^{a-i}
IPB107-F-40E-1	22.04^{abc}	1.3^{Jk}	0.52^{e-n}	68.67^{b-m}	8.11^{c-n}	12.00^{cde}	5.59^{a-f}
IPB107-F-5-5-1	21.46^{a-e}	2.0^{Hij}	0.42^{tu}	69.33^{b-l}	9.22^{b-m}	12.00^{cde}	5.24^{a-g}
IPB BATOLA 5R	21.78^{a-e}	1.0^{K}	0.56^{b-e}	75.67^{abc}	10.30^{a-h}	13.00^{b-e}	4.86^{a-k}
IPB107-F-18	24.06^{a}	3.7^{cde}	0.59^{a-d}	68.67^{b-m}	10.23^{a-i}	13.00^{b-e}	5.01^{a-i}
IPB107-F-127-3-1	23.42^{ab}	1.0^{K}	0.56^{b-e}	70.33^{b-i}	8.78^{c-m}	11.77^{cde}	4.68^{a-k}
IPB107-F-135	21.24^{a-f}	3.0^{efg}	0.49^{k-s}	72.33^{a-f}	9.67^{b-l}	11.67^{cde}	3.96^{c-m}
HHZ5-SAL10-DT1-DT1	21.84^{abcd}	3.0^{efg}	0.59^{a-d}	56.33^{p-w}	11.00^{a-d}	13.00^{b-e}	3.75^{e-m}
IRRI 119	20.85^{a-l}	3.0^{efg}	0.52^{e-m}	58.67^{o-v}	10.00^{a-j}	11.67^{cde}	3.99^{c-m}
IPB107-F-65-3-1	23.96^{a}	2.0^{Hij}	0.51^{e-n}	73.33^{a-d}	12.27^{ab}	11.33^{de}	4.94^{a-j}
Hipa 8	24.25^{a}	2.3^{ghi}	0.61^{ab}	70.00^{b-j}	12.22^{ab}	14.00^{bcd}	6.55^{ab}
Hipa 10	23.67^{ab}	2.0^{Hij}	0.45^{p-t}	55.00^{r-w}	13.06^{a}	18.00^{a}	4.62^{a-k}
Ciherang sub1	23.67^{ab}	4.3^{abc}	0.56^{b-f}	66.00^{d-o}	11.33^{abc}	16.00^{abc}	5.33^{a-g}

Performance of ratoon: There was decrease in appearance of ratoon crop such become shorter than main crop, smaller clumps, smaller culm, early maturity, shorter leaves and panicles and yield was lower but other characters such as the position of the leaves, leaf color and culm erectness were same to the main crop. There was considerable variation in ratooning ability between genotypes. Genotype Siam Narsis, Inpara 2, Cekou A and Korea N did not produce ratoon at all. Instead there were ten ratoon genotypes capable to producing number of living hill at least 50% of the population of main crops, namely: IPB97-F-13-1-1, IPB 4S, IPB107-F-20-5-1, IPB107-F-77-3, IPB 3S, IPB107-F-18-4-1, IPB107-F-16-5, Cekau F10, IR 09F504 and Fatmawati. IPB107-F-20-5-1 produced high percentage of living clump of ratoon but was succebtible to attacked by bacterial leaf blight, sheath blight and neck blast so that the appearance of IPB107-F-20-5-1 was very poor (Table 3). Genotype IPB97-F-13-1-1 has high level of empty grains in the main crop which was due to photosynthate for grain filling into energy to form buds ratoon. Therefore ratoon of IPB97-F-13-1-1 appeared before harvest.

Several factors caused poor ratoon performance were number of clumps do not have seeds, dwarf clump, clump attacked by bacterial leaf blight or blast, lodging clumps, origin of tillers and inequality in time of harvest. A large number of unproductive clumps associated with the emergence of dwarfs clumps resemble grass as in Siam Narsis. This genotype was only able to grow 29.8% ratoon that all were dwarf and subsequently died before the generative phase (Table 3).

The number of lodging clumps was very important in plant population appearance and productivity of genotype. Lodging clumps on ratoon plants most commonly found in genotype IR 09F496, Cekau F10 and IR 09F504 compared to the living clumps of ratoon respectively 25.6, 24.1 and 16.8%. The lodging clumps associated to the origin of ratoon buds, from the node of culm above ground (nodal), rarely found on tillers grown under soil surface (basalt).

Genotypes that produce ratoon crop which ripen simultaneously are ideal idiotype for ratooning. The best level of uniformity in maturity showed by genotype IPB 4S and IPB BATOLA 5R.

Table 3: Ratoon performance of 68 rice genotypes in Bogor, 2012

Genotype	No. of living clumps	No. of effective clumps	No. of clumps attacked by BLB	No. of clump fall	Plant performance	Origin of tiller (Nodal, Basalt)	Harvest uniformity	Day to mature (DAH)	Productivity of ratoon: g clump^{-1}	Productivity of ratoon: Than main crop yield (%)
IPB97-F-13-1-1	74.3	70.0	22.7	2.0	3.0	B	3.0	63.3	10.50^{cg}	91.2
IPB107-F-95	26.3	25.0	1.0	0.0	2.7	B	4.3	66.7	6.58^{hl}	40.9
IPB107-F-14-4-1	16.0	16.0	0.3	0.7	3.0	B	3.0	63.3	14.34^{a}	61.0
IPB107-F-14-5-1	17.7	17.7	0.3	0.0	3.0	B	3.0	60.0	10.88^{cdef}	49.9
IPB107-F-18-4-DJ-1	29.0	27.7	6.0	1.3	2.0	N,B	4.3	62.0	7.81^{ghij}	39.0
IPB Batola 6R	18.0	15.7	2.0	0.7	3.0	B	3.0	68.0	13.13^{abc}	65.3
INPAGO IPB 8G	24.7	19.0	3.0	0.0	3.3	B	3.0	66.3	9.33^{dh}	52.3
IPB 4S	68.0	64.3	15.3	4.7	4.3	B	2.3	61.3	13.00^{abc}	79.7
IPB107-F-7-3-1	2.0	1.3	0.3	0.0	2.3	N,B	4.3	67.0	5.00^{js}	31.7
IPB107-F-13-1	14.0	11.0	2.0	1.0	2.0	N,B	5.0	70.7	8.79^{ei}	37.6
IPB107-F-40E-1	25.3	21.3	3.3	0.3	3.0	N,B	4.3	55.3	7.23^{hijk}	32.8
IPB107F--5-5-1	18.7	16.7	6.3	1.3	2.7	N,B	4.3	68.0	4.60^{jt}	21.4
IPB107-F-20-5-1	81.3	67.7	30.0	0.7	1.0	B	4.3	69.0	7.13^{hl}	65.9
IPB107-F-34-1	45.0	34.7	9.7	0.7	2.3	N,B	5.0	54.0	6.95^{hl}	47.5
IPB107-F-77-3	52.0	52.0	24.7	4.3	2.3	N,B	4.3	60.3	6.34^{hn}	35.9
IPB107-F-10-1	33.3	24.3	14.0	0.0	2.0	N,B	5.0	62.0	6.31^{hn}	33.4
IPB BATOLA 5R	27.7	27.7	12.3	1.3	3.3	B	2.3	56.3	10.89^{cdef}	50.0
IPB117-F-14-2-1	31.7	24.7	16.3	1.7	2.3	B	5.0	56.0	7.60^{ghij}	41.6
IPB105-F-20-1	51.7	34.7	3.0	1.3	2.3	B	3.7	68.3	6.91^{hl}	53.9
IPB 3S	81.3	74.7	2.3	4.0	3.7	B	3.0	56.7	7.53^{gk}	80.0
IPB107-F-60-1	5.0	4.7	0.0	0.7	2.0	N,B	3.7	63.0	2.50^{qv}	13.3
IPB107-F-18-4-1	56.7	51.0	28.7	2.0	2.3	B	5.0	69.0	6.70^{hl}	41.5
IPB107-F-18	28.0	24.0	5.7	0.0	3.7	B	3.0	53.0	11.25^{bcde}	46.8
IPB107-F-16-5	85.7	74.3	39.3	0.0	3.0	N,B	4.3	63.0	5.63^{iq}	36.6
IPB107-F-127	9.7	6.3	0.7	0.0	2.3	N,B	5.0	69.0	10.85^{cdef}	46.3
IPB107-F-135	10.7	6.7	0.7	0.0	2.3	B	5.0	69.0	5.05^{js}	23.8
Siam Linggis	35.0	30.3	0.3	0.0	1.0	N,B	4.7	59.7	4.30^{kt}	31.6
Siam Mutiara	27.0	16.3	0.7	4.3	2.3	N,B	5.0	60.0	3.27^{mv}	20.9
Brenti	16.7	13.0	0.7	2.7	2.0	B	5.0	60.7	3.18^{nv}	24.6
Siam Unus	8.7	8.0	0.7	0.0	2.0	B	5.0	65.0	3.86^{lu}	27.8
Siam Kuning	21.3	19.7	0.0	0.0	2.7	N	5.0	52.7	6.70^{hl}	40.9
Beras Merah	25.7	23.7	6.7	4.3	2.0	N,B	5.0	66.0	0.71^{v}	7.3
Siam Narsis	31.0	0.0	0.0	0.0	1.0	N,B	-	-	-	0.0

Table 3: Countinue

Genotype	No. of living clumps	No. of effective clumps	No. of clumps attacked by BLB	No. of clump fall	Plant performance	Origin of tiller (Nodal, Basalt)	Harvest uniformity	Day to mature (DAH)	Productivity of ratoon (g clump^{-1})	Productivity of ratoon: Than main crop yield (%)
Siam Jerurut	21.0	14.3	2.3	0.7	2.0	N,B	5.0	61.3	5.22^{jr}	44.7
Karya Pelalawan	28.7	23.7	7.7	5.7	2.3	N,B	5.0	65.0	2.64^{pv}	19.5
Cekau F10	52.7	49.0	17.3	12.7	3.0	N,B	4.3	70.3	5.86^{ip}	28.5
Cekau F14	33.0	33.0	8.3	0.0	2.3	N,B	4.3	67.0	10.87^{cdef}	60.0
Cekau F32	38.7	37.0	14.3	2.7	2.0	N,B	4.0	64.7	5.12^{js}	27.6
Cekau F33	33.3	29.7	10.3	1.3	2.7	N,B	4.0	62.7	5.53^{ir}	29.9
Cekau F37	36.7	36.7	8.3	3.7	2.7	N,B	4.7	66.7	5.84^{ip}	29.8
IPB 1R Dadahup	29.0	29.0	5.3	1.7	2.3	N,B	4.3	63.3	3.89^{lu}	27.0
Margasari	24.7	24.0	0.0	2.0	2.0	N,B	5.0	60.3	6.10^{in}	47.6
IPB 2R Bakumpai	38.0	32.3	6.0	3.7	2.7	N,B	3.7	60.0	3.25^{mv}	24.5
Inpara 1	14.3	9.0	0.0	0.7	2.0	N,B	5.0	70.0	5.67^{iq}	32.1
Inpara 2	8.7	0.0	0.0	0.0	1.0	N,B	-	-	-	0.0
Inpara 3	22.0	20.3	11.0	4.7	2.3	N,B	4.3	65.0	6.49^{hm}	42.7
IR 09F164	34.0	34.0	1.7	5.7	1.7	N	5.0	89.0	5.95^{io}	33.5
IR 09F159	14.3	13.3	2.0	3.7	2.3	N	5.0	60.0	4.60^{jt}	24.0
HHZ5-SAL10-DT2-DT1	17.3	8.3	0.0	0.0	2.0	N,B	5.0	72.0	6.34^{hn}	35.7
IR 09F229	40.7	37.7	0.0	2.0	3.0	B	4.3	71.0	1.94^{stuv}	10.7
IR 09F250	50.7	50.7	0.7	6.3	3.3	N,B	3.7	66.0	4.84^{js}	63.6
IR 09F496	50.7	50.7	0.0	13.0	2.3	N	5.0	55.3	7.61^{ghij}	39.9
HHZ5-SAL10-DT1-DT1	13.0	13.0	1.0	4.0	2.7	N,B	3.7	65.3	12.21^{abcd}	55.9
IR 09F504	71.3	47.7	0.0	12.0	2.0	N,B	3.7	64.0	5.09^{js}	28.7
IRRI 119	24.3	24.3	0.0	6.0	2.0	B	5.0	59.3	6.72^{hl}	32.2
Gilirang	6.7	6.7	1.0	0.3	2.0	B	5.0	74.7	1.47^{tuv}	8.7
Cimelati	13.3	13.3	1.0	2.7	2.7	B	4.3	69.7	1.01^{uv}	5.8
Fatmawati	55.7	46.7	10.0	3.0	2.3	N,B	4.3	66.0	3.88^{lu}	24.2
IPB107-F-65-3-1	8.3	8.3	0.0	0.7	2.0	N,B	5.0	74.0	2.33^{rv}	9.7
Cekau A	0.0	0.0	0.0	0.0	2.0	N,B	-	-	-	0.0
Korea N	0.0	0.0	0.0	0.0	2.3	N,B	-	-	-	0.0
Hipa 8	15.7	8.7	0.3	2.3	2.0	N,B	4.3	70.0	14.00^{ab}	57.7
Hipa 10	50.3	36.3	2.0	8.0	2.3	N,B	4.3	70.0	8.81^{ip}	37.2
Ciapus	22.3	18.7	7.7	2.0	2.0	N,B	4.3	68.0	2.83^{ov}	19.4
PSBRC 82 Sub1	47.7	47.7	0.0	7.0	2.0	N,B	5.0	66.3	4.91^{js}	44.3
BP1031F-PN-25-2-4-KN-2	20.3	14.3	3.3	1.3	2.0	B	5.0	72.0	6.75^{hl}	38.9
Ciherang Sub1	42.7	40.3	0.7	5.3	3.0	N,B	3.7	62.0	7.89^{fj}	33.3
Inpari 2	14.7	3.3	6.0	0.0	1.3	B	5.0	56.3	5.13^{js}	40.5

Genotypes that were classified as somewhat uniform were: IPB97-F-13-1-1, IPB107-F-14-4-1, IPB107-F-14-5-1, IPB Batola 6R, Inpago IPB 8G, IPB 3S and IPB107-F-18.

Genotype IPB107-F-18 and Siam Kuning mature at the age of 53 days after the main crop harvested (DAH). Furthermore, there were several genotypes can already harvested less than 60 days since the main crops harvested, namely: IPB107-F-34-1, IR 09F496, IPB107-F-40E-1, IPB117-F-14-2, Inpari 2, IPB BATOLA 5R, IPB 3S, IRRI 119 and Siam Linggis. The longest maturity of ratoon was found in IR 09F164 which was harvested 89 days after the main crop harvest.

Relationships between main crop characters and productivity of ratoon: The main crops appearance were generally reflected in ratoon, therefore selection for main crop ideotype was important for good ratoon. Genotypes that have large culm will produce no dwarf ratoon. Genotype Siam Narsis which has slender and tall culm did not produce ratoon. Tillers grew from the Siam Narsis stubble were dwarf and ineffective. Unlike the genotype IPB107-F-14-4-1 that had culm diameter 0.62 cm produce good ratoon yield.

There was a tendency that vigorous plants as shown in plant height and clump weight at 30 DAT had good ratooning ability with r values of 0.422 and 0.415, respectively. Ratoon productivity tends to be high in genotypes with high clump weight and plant height at 30 DAT.

Total of 73% of stay green plants (the color scale of leaves at harvest > 3.5) resulted in high ratoon productivity or at least 7.5 g clump^{-1} grain yield. Furthermore, as many as 81% of non stay green plant (the color scale of leaves at harvest is 2) resulted in low productivity <7.5 g clump^{-1} grain yield.

Analysis of correlation between main crop characters and productivity of ratoon showed that productivity, color of leaves, culm diameter, culm wall thickness, plant height at 30 DAT and clump weights at 30 DAT of main crop significantly correlated to the productivity of ratoon. The main crop characters affect that strongly correlate to productivity of ratoon was culm diameter (r = 0.72**), followed by plant height 30 DAT (r = 0.42**), clump weight 30 DAT (r = 0.41**), productivity of main crops (r = 0.33**) and color of leaves (r = 0.22**). The larger plant culm, the better ratoon generated.

The correlation coefficient of main crop productivity and ratoon productivity was 0.33 while the direct effect was only 0.05. Character of plant height 30 DAT also had a correlation coefficient greater than the value of its direct effect (Fig. 1). Among the various characters observed, the character of culm diameter has the highest correlation to productivity of ratoon with a strong correlation coefficient 0.72 and direct effect 0.62.

Selection of the best genotype based on main crop character and ratoon: Selection of genotypes based on many characters at once, need consider the value of variance components represented by F value in Anova is very significant, high correlation between the characters that will be used as selection criteria with the yield and a fairly high heritability. According to McWhiter (1979), the criterion to estimates value of heritability are as follows: high heritability if H> 0.5; medium heritability was 0.2<H<0.5, low heritability H<0.2. The main crop traits such as productivity, color of leaves at harvest, culm diameter, culm thickness, plant height at 30 DAT and clump weights at 30 DAT had F-value very significant and very significant correlated to productivity of ratoon (Table 4), so the main crop variables have three requirements as the selection criteria.

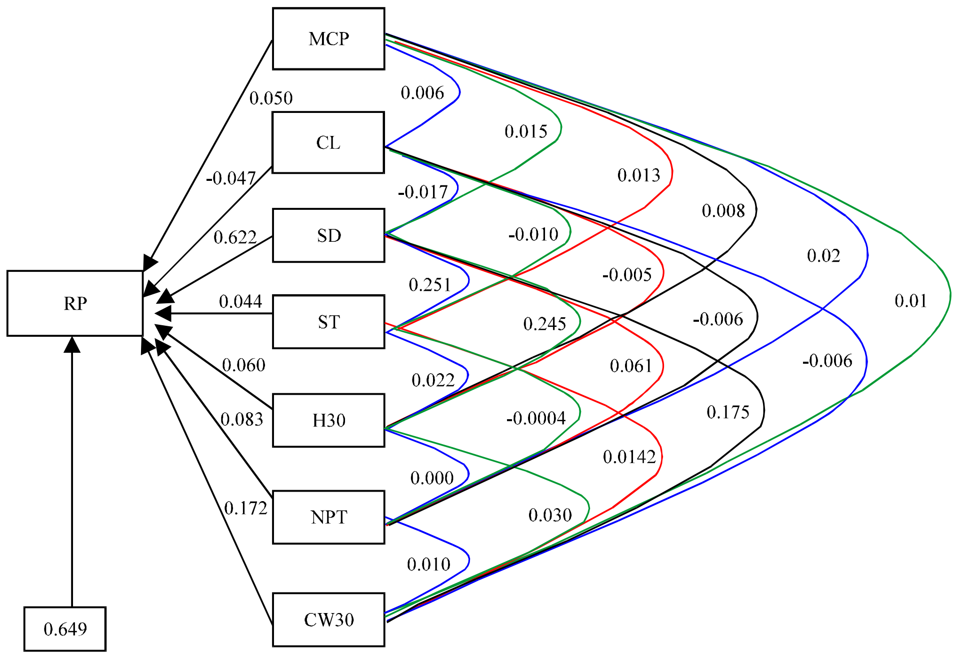

Fig. 1: Direct and indirect effects of the seven main crop characters to the productivity of ratoon. RP: Ratoon productivity, MCP: Main crop productivity, CL: Color of leaf, SD: Culm diameter, ST: Culm thickness, H30: Plant height 30 DAT, NPT: No. of effective tiller, CW30: Clump weight 30 DAT

Table 4: Coefficient of variation correlation of main crop characters to ratoon yield

Variables	CV (%)	Correlation coefficient
Main crop productivity	12.44	0.33**
Color of leaves at harvest	16.57	0.22**
Culm diameter	5.32	0.72**
Culm thickness	7.79	0.38**
Plant height at 30 DAT	6.46	0.42**
No. of effective tiller	18.01	0.18 ns
Clump weight at 30 DAT	25.55	0.41**

ns: Not significant, **Significant at p>0.5

The six main crop variables above used as selection criteria to select rice genotypes with ratoon potential by index and selected nine genotypes, namely: IPB97-F-13-1-1, IPB107-F-14-4-1, IPB107-F-14-5-1, IPB Batola 6R, Inpago IPB 8G, IPB 4S, IPB BATOLA 5R, IPB 3S and IPB107-F-18 (Table 5). In addition, characters of ratoon crop such as productivity of ratoon, the difference of main crop to ratoon productivity <60% and uniform maturity (Table 6) tighten the selection so that the selected genotypes were best ratoon genotype. Nine genotypes were selected as ratoon rice by using indeks selection, namely.

Some criteria of ratoon genotype desired in this study were those with ratoon productivity above 7.5 g clump^{-1} or at least 1.5 t ha^{-1} of Dry Milled Grain (DMG), new type rice plant, difference of yield of main crop and ratoon not more than 60% or yield of ratoon at least 40% of the main crop with uniform maturity. Genotype IPB97-F-13-1-1 has small a difference in productivity between ratoon and the main crop (8.9%), followed by IPB 4S (20.3%) and IPB 3S (20%). All three genotypes were new plant type rice.

Table 5: Index selection of nine ratoon genotype based on the main crop characters and direct effect of main crop characters to productivity of ratoon

Genotips	Productivity of main crop	Leaf color	Culm diameter	Plant height 30 DAT	No. of effective tiller	Clump weight 30 DAT	Index
IPB107-F-14-4-1	23.50	4.33	0.627	75.33	10.11	6.83	7.90
IPB Batola 6R	20.11	2.33	0.600	71.33	9.44	6.17	7.39
IPB 4S	16.31	3.67	0.597	79.00	8.40	6.13	7.51
INPAGO IPB 8G	17.85	5.00	0.596	71.67	9.00	6.18	7.14
IPB107-F-18	24.06	3.67	0.587	68.67	10.23	5.01	7.23
IPB BATOLA 5R	21.78	1.00	0.563	75.67	10.30	4.86	7.62
IPB107-F-14-5-1	21.81	4.67	0.557	69.33	8.89	4.63	6.91
IPB97-F-13-1-1	11.52	4.00	0.563	75.33	6.56	5.51	6.75
IPB 3S	9.41	2.00	0.530	76.33	9.00	5.45	6.97
Direct effects of main crop characters to productivity of ratoon	0.05	-0.047	0.622	0.06	0.083	0.172	

Tabel 6: Productivity of nine ratoon genotype, difference of main crop and ratoon productivity and uniform maturiy

Genotip	Productivity of ratoon	Difference of MC and R productivity (<60%)	Mature uniformity
IPB107-F-14-4-1	14.34	39.0	3.0
IPB Batola 6R	13.13	34.7	3.0
IPB 4S	13.00	20.3	2.3
INPAGO IPB 8G	9.33	47.7	3.0
IPB107-F-18	11.25	53.2	3.0
IPB BATOLA 5R	10.89	50.0	2.3
IPB107-F-14-5-1	10.88	50.1	3.0
IPB97-F-13-1-1	10.50	8.9	3.0
IPB 3S	7.53	20.0	3.0

Yield trials of ratoon genotypes in tidal swamp environment: Evaluation of selected genotypes in tidal acid sulphate soil with type B water flooding showed significant effect of genotype on the yield of main crop, yield of ratoon, as well as the main crop + ratoon. All genotypes showed lower growth and yield compared to the yield in Bogor. These low yield was related to high abiotic stresses in acid soil with pH 4.08, high iron 617 mg kg^{-1} Fe and pyrite 1032 mg kg^{-1} FeS_2. Lightest bronzing symptoms occured in Inpara 2 and heaviest in genotype IPB107-F-14-5-1 and IPB BATOLA 5R due to high Fe concentration. Bronzing was worse with increasing age of the plant.

Genotype Inpara 2 produced 3.52 t ha^{-1} of dry milled grain (dmg) from the main crop, the highest among the other genotypes but only produce 0.53 t ha^{-1} dmg from ratoon. Other genotypes produced less grain from the main crop but ratoon can produce up to more than 50% of the main crop yields so that the total main crop yields and ratoon can reach 4 t ha^{-1}. Genotype IPB97-F-13-1-1, IPB107-F-14-4-1, IPB 4S and IPB 3S able to maintain appearances until harvest with little missing hills and panicle mature simultaneously (Table 7). This situation cannot be separated from their tolerance to some major stress in acid sulphate soil.

The total yield of main crop + ratoon of genotype IPB97-F-13-1-1, IPB107-F-14-4-1, IPB Batola 6R, Inpago IPB 8G, IPB 4S, IPB 3S and IPB107-F-18 did not significantly different to the yield of main crop of Inpara 2. The yield of main crop genotype IPB97-F-13-1-1 and IPB 4S were 2.85 and 2.82 t ha^{-1}.

Table 7: Yield of genotype ratoon in tidal acid sulphate soil area, Pulang Pisau (2012-2013)

Genotype	Yield of main crop (t ha^{-1})	Yield of ratoon (t ha^{-1})	Main crop+ratoon (t ha^{-1})
IPB97-F-13-1-1	2.85^{ab}	1.55^{ab}	4.40^{a}
IPB107-F-14-4-1	2.47^{b}	1.60^{a}	4.07^{a}
IPB107-F-14-5-1	2.17^{b}	0.80^{def}	2.97^{b}
IPB Batola 6R	2.75^{b}	1.03^{cde}	3.78^{ab}
INPAGO IPB 8G	2.55^{b}	1.17^{bcd}	3.72^{ab}
IPB 4S	2.82^{ab}	1.53^{ab}	4.35^{a}
IPB BATOLA 5R	2.12^{b}	0.73^{ef}	2.85^{b}
IPB 3S	2.47^{b}	1.53^{ab}	4.00^{a}
IPB107-F-18	2.37^{b}	1.27^{abc}	3.63^{ab}
Inpara 2	3.52^{a}	0.53^{f}	4.05^{a}
CV (%)	15.64	18.47	13.52
Pr>F	0.0234	<0.0001	0.0185

DISCUSSION

Performance of ratoons and relationship between main crop character and productivity of ratoon: There were variation in ratooning ability between genotypes known as genetic influences but variation of ratooning ability in genotype was environmental influences. Ratooning ability is genetic but the environment is very strong intervene. Missing hills was found in all genotypes in different number. Genotype IPB 3S produce lower missing hill 22.8%. This relate to the genotype ability to maintain ratoon buds viability on the culm, resistance to disease and availability of food reserves in the culm.

Ratoon height was shorter than the main crop and only 11 genotypes were able to achieve = 80 cm. Ratoon height associated to the origin of tiller from nodal or basalt. Almost all high tillers were growing from basalt. According to Yang *et al.* (2011), the plants of ratoon have to grow taller to extend the period of growth so grain yield can be achieved. The faster increase in height and weight of plants in vegetative phase can be used as selection criteria for ratoon rice (r = 0.4). One feature of a plant grows rapidly was the rate of increase node number quickly. Plants have rapid rate of node increase number will have more tillers and panicles and weight of leaves, culms and panicles higher. The number of nodes in the main culm has a significant positive direct effect on weight of culm and maximum tiller number (Samonte *et al.*, 2006). High culm weights reflecting the large culm and dense. Such culm would produce good ratoon. It was related to optimal function of roots and leaves so the plants can utilize all resources properly to accumulate biomass. The good character of both roots and leaves can give positive effect on ratoon. According to Zhang *et al.* (2010), increasing the activity of main crop roots after heading is important to produce high yield ratoon based on the high ability of buds to survive.

Cultivars with high dry weight had high nutrients in the culm. There were differences in nutrient content the main crop between cultivars (Nakano *et al.*, 2009). Morphological appearance of main crops such as large culm and green, dense clump and leaves and stumps remain vigor and green were the character determines the ratooning ability (Susilawati *et al.*, 2010).

Nitrogen plays an important role in breaking the tiller bud from dormancy and significantly promoted growth. The growth during the ripening process is enhanced by the high concentration of N in the leaves. This is the reason for the importance of stay green leaf trait to produce a good ratun (Dingkuhn *et al.*, 1991). Color of the leaves at harvest can used as one determinant of good ratoon generated. The main crop leaves are still green at harvest indicates there are many Nitrogen (N) in the leaves, culm and node.

Variation in ratoon between genotypes may be associated to variations in N plant as a result of genetic different. Majority (73%) stay green leaves genotype produce high productivity of ratoon. This is contrast to Arumugachamy *et al.* (1990) who reported that the aging of main crop leaves at harvest and carbohydrate content in the main culm of the plant does not significantly affect the yield of ratoon. The IPB 4S showed good performance, stay green leaves, large culm diameter 0.597 cm, vigorous and highest number of fresh culms (8.67 rods). This is consistent to Balasubramanian *et al.* (1992) who states that delays the aging of leaves, high levels of carbohydrates in the culm and the big culm were some reason for the high number of tillers ratoon. High productivity of main crops did not guarantee for high productivity of ratoon. Many genotypes rank changed based on the yield of ratoon when compared to the same genotype ranked based on the yield of main crop. However, this character has a broad genetic variability and positively correlated with the yield of ratoon so although can not be used as the sole criterion, selection the main crop for high yield and good ratoon still can be done freely. Genotype HIPA 10 and IPB107-F-65-3-1 produced 5.88 and 5.6 t ha^{-1} grain yield from main crop but only 492 kg ha^{-1} and 45.8 kg ha^{-1} grain yield from ratoon, respectively (Table 2). In addition to genetic factors, it was believed relate to the availability of nutrients for main crop growth phase. Islam *et al.* (2008) reported that the highest yield of main crops produced by fertilization of 120 kg ha^{-1} N, 65 kg ha^{-1} P_2O_5, 70 kg ha^{-1} K_2O, 13 kg ha^{-1} S and 4 kg ha^{-1} Zn. But in the ratoon crop, the highest yield was obtained by fertilization 150 kg ha^{-1} N, 85 kg ha^{-1} P_2O_5, 90 kg ha^{-1} K_2O, 13 kg ha^{-1} S and 4 kg ha^{-1} Zn. This suggests that to produce a good ratoon, fertilizer should given over the main crop need so that the plant can save it for ratoon growth.

The number of main crop tillers at 30 DAT was not significantly correlated to ratoon productivity. Many lines produce many tillers in main crop but their size is small or slim so cannot produce ratoon as Siam Narsis has. According to Yang *et al.* (2004), the most influential variable on yield of ratoon is the number of effective tillers of ratoon but in the main crop, the variable number of grains per panicle more influence on the yield than the number of effective tiller. According to Cai *et al.* (2011) the ability of varieties to produce different number of tillers, affect to panicle number of ratoon crop. Therefore, the main crop of ratoon varieties must have high tillering ability.

In this study, the most strong main crop characters affect productivity of ratoon were culm diameter ($r = 0.72$). The larger plant culm, the better ratoon generated. Therefore, according to Balasubramanian *et al.* (1992), the diameter of culm of the main crop can be used as selection criteria for rice ratoon.

The small direct effect between main crop and ratoon productivity showed that main crop productivity less effective as a selection criterion for rice ratoon. Correlation coefficient of main crop color of leaves with ratoon productivity was 0.22 (positive) while its direct effect was only 0.047 (negative). This is meaning that not direct effect which causes the correlations rather indirect effect. Thus the character cannot used as sole selection criteria in the direct selection because it will not effective. Oad *et al.* (2002) were report that the parameters of ratoon have low positive direct effect.

The small difference value between correlation (0.72) and direct effect (0.62) character main crop culm diameter and productivity of ratoon, meaning the correlation describes the real relationship and direct selection will effective through culm diameter trait of the main crop. According to Wu *et al.* (2011), the large culm trait usually exhibited greater plant size, larger culm diameter and lower number of tillers. This character is important because it relates to lodging resistance, biomass accumulation, flag leaf length and width, larger leaf vascular bundles, more culm vascular bundles, higher transpiration rate, photosynthetic efficiency and transport apoplastik ability.

Selection of genotypes can based on the high yield of ratoon, many effective tillers, many panicles per hill, long panicle and high-ranking ratoon (Oad *et al*., 2002). If there are two characters that are not correlated but both characters have a significant direct effect on the characters that directly affect grain yield, so the both characters can used as selection criteria for yield (Samonte *et al*., 2006).

The contribution of each main crop character separately to the ratoon productivity was relatively small. The best ratoon obtained when several characters were present together. Genotype IPB107-F-14-4-1 have highest productivity ratoon appears to have also some important characters like green leaves at harvest, large culm diameter 0.63 cm, culm thickness 0.09 cm, number of effective tillers 10.11, vigorous and showed good performance. Genotype IPB107-F-14-4-1 followed by HIPA 8 in ratoon productivity and it's main crop productivity highest among all genotypes tested. HIPA 8 also has some good characters are present as well, such as: Good performance, culm diameter 0.61 cm, clumps weight 30 DAT 6.55 g $clump^{-1}$ and number of effective tillers 12.22. Genotype Inpago IPB 8G was the best looking, most green leaf color (dark green), large culm diameter 0.596 cm, vigorous and had many fresh culms at harvest. IPB-97-20 showed good performance, green leaf, culm diameter 0.597, vigorous and highest number of fresh culm 8.67. In contrast, genotype Siam Narsis have not all the superior characters. Genotype Siam Narsis had small culm diameter that is 0.451 cm, senescence leaves at harvest time, not vigorous, tall slender plant and performance not good. Nevertheless Siam Narsis had thick culm wall 0.068 cm, the only one superior character it has. Similar to Siam narsis there were genotype Cekau A and Korea N.

Selection of the best genotype based on main crop character and ratoon: Ratoon productivity is the main purpose and the most important criteria in rice ratoon selection. Ratoon productivity has a wide genetic variability so that selection for high productivity of rice ratoon can do on this character. These results are similar to Ichii and Kuwada who demonstrate considerable ability to generate ratoon between genotypes (Ichii and Kuwada, 1981), genotype effect on the yield of ratoon (Susilawati *et al*., 2012) or ratooning ability was different between varieties (Balasubramanian *et al*., 1992). Productivity illustrates the potential of each individual genotype to produce ratoon. Unlike the character productivity, character yield per unit area is more real but often do not illustrate the potential genotype because the effect of genotype x environmental is large so there are many missing hills. Genotype IPB107-F-14-4-1 had a great ratoon potential and high productivity (14.34 g $clump^{-1}$) but the real yields only 0.53 t ha^{-1}. The low yield obtained IPB107-F-14-4-1 due to many clumps missed. According to Turner and Fund (1993), the factors affect yield of ratoon is not quite clear known. However, missing hill is not genetic but environmentally. Therefore, such genotypes need to be tested in different agro-ecosystems.

In addition high productivity of ratoon, uniformity to mature is also an important criterion for ratoon. The simultaneously time to harvest produce rice yield with a low percentage of green grains, save labor and low harvest costs.

Farming system of ratoon expect the accumulation yield from main crop and ratoon is high. High yield will obtained if the productivity of main crops and ratoon equally high. Therefore, the selection can directed to the genotypes have small difference in main crop and ratoon productivity. Adigbo *et al*. (2012) reported that the yield of the main crop was 5.0-7.3 t ha^{-1} with the yields of ratoon between 1.0-4.7 t ha^{-1} dry grain or yield of ratoon can reach 64% of the main crop.

Yield trials ratoon genotypes in tidal environment: The low yields of all genotype planted in tidal land were related to abiotic stresses particularly high acid soil (pH 4.08), iron (617 mg kg^{-1} Fe) and pyrite (1032 mg kg^{-1} FeS_2). According to Kampfenkel and Montagu (1995), under oxidative conditions, pyrite oxidizes so harmful to plants and Fe toxicity causes oxidative stress. All plants showed symptoms of bronzing which according to Romheld and Nikolic (2006) is due to Fe toxicity. Bronzing characterized by rust spots or small brown stain spreading on leaf, older leaves fall prematurely and roots turn into brown. The decrease in rice yields due to iron poisoning range from 40-100% (Aung, 2006). The development of plants in acid sulfate soil is focused on adaptation to Fe, Al and acidity (Wu *et al*., 2014; Shamshuddin *et al*., 2013; Kang *et al*., 2010; Sahrawat, 2010). Although yield of main crop genotype IPB97-F-13-1-1 and IPB 4S relatively low if compared to the yield obtained when the genotype was grown on a better environment in Bogor but the narrow difference yields of main crop and ratoon promising that genotypes potential as a new type ratoon paddy. Repair tidal environment with cultivation techniques are expected to improve the yields of main crop and ratoon. Thus the genotypes IPB97-F-13-1-1, IPB107-F-14-4-1, IPB 4S and IPB 3S were potential as rice ratoon for tidal swamp area that is classified as type B and acid sulfate soil.

CONCLUSION

The ability of each genotype to produce ratoon is varying widely. Selection can be done using a secondary character, i.e., culm diameter, fast growth and vigor, stay green leaf, lot number of effective tillers and high productivity of main crops. By using multiple selection criteria at once, screened nine genotypes are potentially as rice ratoon IPB97-F-13-1-1, IPB107-F-14-4-1, IPB107-F-14-5-1, IPB Batola 6R, Inpago IPB 8G, IPB 4S, IPB BATOLA 5R, IPB 3S and IPB107-F-18. Of the nine genotypes, only IPB97-F-13-1-1, IPB107-F-14-4-1, IPB 4S and IPB 3S capable to produce yield of ratoon at least 1.5 t ha^{-1} dry milled grain or increasing the yield over 50% of the main crop when tested in suboptimal tidal area type B and acid sulphate soil, thus the four genotypes can be used as ratoon rice in tidal land.

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