Early Population Development of Red Rice for Lodging Resistence

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ABSTRACT

Rice plants having no lodging resistance characters tend to decrease the yield. The selection of rice plants with lodging resistance characters need to be done in order to get the parent for plant breeding. The purpose of this research was to investigate the characters of upland rice related to the rate of lodging and to develop the upland rice genotype with lodging resistance characters as the parent of plant breeding. This research was conducted from January to June 2017 in the Research and Experimental Garden of Faculty of Agriculture, Fishery and Biology. This research used Randomized Block Design with 4 block replication. The treatment of this research was the rice genotypes of Balok accession, Banyuasin, Inpago 4, Inpago 8 variety, MP2046, and MR1512 mutant. The result of the research showed that Banyuasin variety had lodging resistance characters better than other genotypes because it had short stem and dry weight stem. For these characters, it had the potential to be the parent for plant breeding activities. The selected genotypes were used as parent plants for breeding program. There were 60 furrows of F1 red rice obtained as red rice early population with lodging resistance.

Keywords: genotype, lodging resistance, selection, upland rice

INTRODUCTION

Indonesia's rice consumption is the highest compared to other food commodities like potatoes, sago, cassava, and other tuber commodities. Rice (*Oryza sativa*) has an important role as the main source of carbohydrate with 70 – 80% calorie and 40 – 70% protein for per capita needs per day (Sadimantara *et al.*, 2013). According to Nurmala (2003), every 100 grams of rice contains 8.7% protein, 1.5% crude fat, 71.8% carbohydrate, 2.2% fiber, 0.66 mg thiamine, 0.25 mg riboflavin, 1.3 mg niacin, 9.0 mg Fe, 3.0 mg Zn, vitamin A, and vitamin B complex.

Indonesia's rice needs have increased since 1980. Indonesia's rice imports increased by 1.87 million tons in 2012 to 1.16 million tons per month in October 2016 and continued to experience an increase in imports by year-end (Kementan, 2016). Indonesia's national rice production continued to increase by 65 million tons in 2011 to 75 million tons in 2015 (BPS, 2016). However, the increase in production has not been able to meet the national rice needs which resulting in rice imports. This is because the growth of food commodity productivity is relatively slow compared to demand growth followed by the increase in population (Prabowo, 2010). One of the possible efforts to meet the national rice demand is the activity of plant breeding. Plant breeding aims to create varieties which have high yielding and in accordance with ecosystem, social, cultivation, and community interest conditions (Susanto *et al.*, 2003). Methods of plant breeding by utilizing local varieties are more favorable with the aim to improve plant genetics. Utilizing resistant genes possessed by local varieties in breeding can enhance the superiority of a best quality variety (Sitaresmi *et al.*, 2013).

The local upland rice has good genes such as tolerance to pests and diseases and is resistant to local environmental stress. The weakness of local upland rice variety in generalist the production takes long time, the production is relatively low, and the plants grow high causing it to be more susceptible to lodging condition (Riyatno *et al.*, 2011). According to Pasaribu *et al.* (2013), local upland rice often falls when entering the generative phase resulting in reduced yields and decreased grain quality.

The lodging resistance test can be conducted by using the lodging index of 0 - 9. The lowest index is 0 which means not falling and 9 means very high level of over 80% (Deptan, 2003). The lodging character can be improved by plant breeding method, in which the implementation of this method is to obtain superior upland rice variety which has high early-ripening age, lodging resistance, and productivity.

Based on the fact and the data mentioned above, in order to develop upland rice varieties with lodging resistance which can be used as the source of lodging resistance genes, it is necessary to do research on evaluation and selection of upland rice plants having lodging resistance.

MATERIALS AND METHODS

Time and Place

This research was conducted from January to July 2017. The research activity was conducted in the Research and Experimental Station of Faculty of Agriculture, Fishery and Biology in Bangka Belitung University.

Tools and Materials

The tools are used in this research were *cangkung, parang, kedik*, ruler, measuring tape, spring balance, sprayer, tractor, analytical scales, oven, and stationeries. The materials are used in this research were rice seed varieties of MR1512, INPAGO 8, Banyuasin, MP2046, INPAGO 4, *CerakNyelanding* accession, urea fertilizer, chicken manure, KCl, and TSP.

Research Methods

This research used randomized block design experiment method with single factor of upland rice variety that is the variety of MR1512, Banyuasin, INPAGO 8, MP2046, INPAGO 4, and *CerakNyelanding* accession. Each treatment was repeated four times to obtain 24 units of experiment. The experimental unit was a plot with spacing of 25 cm and plot size of 1.25 × 3.25 m^2. Each plot consisted of 48 populations of upland rice plants with 1,154 total population of rice.

The treatments were carried out as follows:

MR15	: MR1512 Mutant	BYN	: Banyuasin Variety
INP8	: INPAGO 8 Variety	INP4	: INPAGO 4 Variety
MP46	: MP2046 Mutant	BLK	: Balok Accession

Observed Variables

The variables were observed based on description for *Oryza sativa* L (IRRI-IBPGR, 1980) and Guide of Rice Crop Characterization and Evaluation System (Deptan, 2003). Observed characters include the index of lodging, stem strength, dry weight stem, stem diameter, stem strength, percentage of filled seeds, percentage of empty seeds, average weight per seed, maximum number of tillers, number of productive tillers, panicle length, plant height, and stem bark thickness.

Data Analysis

The data of the research were analyzed using F-test with 95% of reliability and continued with Duncan Multiple Range Test (DMRT) with 95% of reliability level if there was significant difference. Data analysis was performed using Statistical Analytic System (SAS) application.

Crossing of Mutant Rice Furrow with Lodging Resistance Varieties

The crossing was conducted by planting selected rice genotypes used as plant breeding in a plastic bucket. Each bucket contained three plants from each genotype. The planting was conducted in three stages, in which each stage was planted at two weeks intervals. The time interval applied for planting was intended to anticipate the difference in blooming time of older plant breeding. F1 crops from the crossing were then planted for reproduction and F2 population formation.

RESULTS

Selection of Red Rice with Lodging Resistance Genotypes

The evaluation of several genotypes of upland rice was conducted on 6 upland rice genotypes, including Balok accession, MR1512 mutant, MP2046 mutant, Banyuasin, Inpago 4, and Inpago 8 variety. The investigation result on stem strength parameters, maximum number of tillers, productive number of tillers, long panicle, plant height, and stem bark thickness showed that there was a real influence. The parameter of dry weight stem, stem diameter, percentage of pithy seeds, and percentage of empty seeds showed no real effect. The parameters of the average weight of filled seeds with not significant influence (Table 1).

Banyuasin variety had the highest dry weight stem (2.01 g), maximum number of tillers (27.60 stems), highest number of productive tillers (20.90 stems), and shortest plant height (88.07 cm) compared to other genotypes. Banyuasin variety had a large stem diameter (6.32 mm) which was not significantly different from Inpago 4 variety (6.72 g), short panicle length (23.37 cm) which was not significantly different from MP2046 (20.35) and percentage of empty seeds (27.83%) and pithy (72.17%) which was not significantly different from Inpago 4 variety (26.05% and 73.95%) but had low stem strength (697.3 g) and thin stem bark (0.10 mm) (Table 2).

Table 1. The investigation result of 6 upland rice genotypes

Variables observed	F-count	Pr>F	CD (%)
Dry weight stem (g)	4.03*	0.0161	26.99
Stem diameter (mm)	4.47*	0.0107	7.61
Stem strength (g)	10.51**	0.0002	29.29
Maximum number of tillers	12.47**	<0.0001	20.53
Productive number of tillers	9.69**	0.0030	18.76
Panicle length (cm)	5.37**	0.0050	11.35
Plant height (cm)	51.21**	<0.0001	5.12
Stem bark thickness (mm)	5.37**	0.0050	13.23
Percentage of filled seed (%)	3.60*	0.0243	17.91
Percentage of filled seed (%)	3.60*	0.0243	28.14
Average weight of filled seed (mg)	1.75 ns	0.1821	18.93

ns = non-significance; * significant at α 0.05; ** significant at α 0.01; CD = Coefficient of Diversity

Inpago 4 variety had stem diameter (6.72 mm), the highest percentage of seeds (73.95%), the lowest percentage of empty seeds (26.05%) and the heaviest weight average (28.01 mg). Inpago 4 variety had heavy dry weight of stem (1.16 g) which was not significantly different from Balok accession (1.17 g), Inpago8 variety (1.79 g), MR1512 (1.07 g) and MP2046 mutant (1.17 g). However, Inpago 4 variety had small number of tillers (17.18 stems), long panicles (30.07 cm), and thin bark stem (0.09 mm) (Table 2).

Balok accession had a thick bark stem (0.12 mm) which was not different from Inpago8 (0.12 mm) and thick stem diameter (6.31 mm). Balok accession had a maximum number of tillers (13.08 stems) and low productivity (11.05 stems), the highest canopy (150.52 cm), the percentage of filled seeds (52.46%), and the percentage of empty seeds (47.54%) (Table 2).

MR1512 mutant only had favorable point on thick stem diameter (6.50 mm). The other characters of MR1512 was it had the lowest dry stem weight (1.07 g), small number of maximum tillers (12.93 stems), the smallest number of productive tillers (10.65 stems), high canopy (147.42 cm), low stem bark thickness (0.09 mm), the lowest percentage of filled seeds (49.38%), and highest percentage of high empty seeds (50.62%)(Table 2).

Inpago 8 variety had the strongest stem strength (1583.3 g) and the thickest bark stem (0.12 mm) which was not different from Balok accession (0.12 mm), but it had low maximum number of tillers (13.82 stems) and low number of productive tillers (12.20 stems). MP2046 mutant had the shortest panicle length (20.35 cm) and large stem diameter (6.49 mm), but had the lowest number of tillers (12.37 stems), low productive tillers (11.52 stems), high canopy (143.85 cm), and thin bark stem (0.09 mm) (Table 2).

Table 2. Average variables of various upland rice genotypes

Character	Rice genotype					
	Banyu-asin	Inpago 4	Inpago 8	MP2046	MR1512	Balok
Dry weight stem (g)	**2.01a**	1.16bc	1.79ab	1.17bc	1.07c	1.17ab
Stem diameter (mm)	6.32a	**6.72a**	5.28b	6.49a	6.50a	6.31a
Stem strength (mm)	697.30cd	977.3bc	**1583.3a**	362.0d	708.50cd	1301.8ab
Maximum number of tillers (stem)	**27.60a**	17.18b	13.82b	12.37b	12.93b	13.08b
Productive number of tillers (stem)	**20.90a**	15.95b	12.20bc	11.52c	10.65c	11.05c
Panicle length (cm)	23.37bc	30.07a	25.75b	**20.35c**	23.55bc	24.17bc
Plant height (cm)	**88.07c**	123.65b	120.42b	143.85a	147.42a	150.52a
Stem bark thickness (mm)	0.10b	0.09b	**0.12a**	0.09b	0.09b	**0.12a**
Percentage of pithy seed (%)	72.17ab	**73.95a**	55.21bc	63.44abc	49.38c	52.46c
Percentage of empty seed (%)	27.83bc	**26.05c**	44.79ab	36.58abc	50.62a	47.54a
Average seed weight (mg)	27.37a	**28.01a**	22.54a	19.93a	21.29a	15.85a
Lodging	**1**	9	9	9	9	9
Lodging resistance	**1**	9	9	9	9	9
Shed	7	7	5	3	5	7

Values followed by the same letter on the same line means no significant difference based on DMRT α 0.05; KrB: 1 = lodging plant <20% (lodging resistant) 9 = lodging plant > 80% (sensitive). KtB: 1 = strong (not curved), 9 = very weak (whole flat plant). Shed: 3 = slightly difficult (1-5% shed), 5 = medium (6-25% shed), 7 = rather easy (26-50% shed)

Table 3. Correlation between the lodging level and the plant character

	Plant height	Dry weight	Stem diameter	Stem strength	Stem bark thickness
Lodging plant	**0.85**	**-0.76**	-0.05	0.27	0.06

The scoring data (Table 2) on lodging and lodging resistance parameter showed that all genotypes were on lodging state which was over 80% (score 9) except in Banyuasin variety with less than 20% (score 1) and had straight stems (1). The highest shed parameter happened to Balok accession, Inpago 4, and Banyuasin variety with shed rate of 26 - 50% (score 7). Inpago 8 variety and MR1215 mutant had 6 - 25% (score 5) and MP2046 had 1 - 5% (score 3) of shed percentage. The highest score of maximum number of tillers parameter with more than 25 tillers was found in Banyuasin variety (score 1), while other genotypes had tillers around 10 to 19 (score 5). The highest scoring of plant height was found in Banyuasin variety with plant height 88.07 cm (score 1), Inpago 8 and Inpago 4 variety with height of 120.42 cm and 123.65 cm respectively (score 5), and other genotypes with height above 125 cm (score 9).

Crossing of Mutant Furrows with Selected Genotypes

The result of the evaluation showed that Banyuasin variety had the best lodging resistance level compared to other rice genotypes. Based on the result, Banyuasin variety was used as the plant breeding parent of red rice crossing with lodging resistance. Other furrows used as crossing parent were MR1512 mutant (red-colored rice, high yield) and Inpago 8 variety (high yield).

The percentage of success between MR1512 and Banyuasin varieties was 18.6%, and the crossing of MR1512 genotype with Inpago 8 was 51.5%. The crossing was then replanted to get the first generation (F1). The result obtained from planting was 60 F1 furrows of red rice with growth percentage of 14.85%.

DISCUSSION

Banyuasin variety is a rice plant genotype which has good lodging resistance based on plant height character, stem diameter, and dry weight stem. The average height of Banyuasin rice variety is 88.08 cm and is classified as short (group 1 with height less than 90 cm) unlike other genotypes with high plant size (group 9 with plant height above 125 cm) (Deptan, 2003). Plant height is the main factor causing lodging in rice, wheat, and other cereals. Permana (2010) asserts that the plant height determines the lodging level. As stated by Saniah *et al.* (2011), the plant height is the main target in improving plant lodging resistance.

Rice plant which has a relatively short stem is more difficult to lodge than the relatively high plant. On the word of Riyanto *et al.* (2011), the increase in height of upland rice makes it easier for the plant to lodge. Guirfu *et al.* (2006) states that the high characters of plant have a great influence on the lodging state. High rice crops will result in a high yield loss due to the lodging state. According to Sitaresmi *et al.* (2013), the high rice crops such as local rice plants is susceptible to lodging which brings impact to yield decrease. Plants which have short height and strong stem will increase yield.

The height of rice plants is controlled by growth genes. Kinosita (1995) in Kamara (2015) states that 60 dwarf genes (d1 - d60) and semi-dwarf genes (sd1-sd7)have been found. These genes are either artificial genes or naturally found genes. Sd1 gene is one of the most developed genes in plant breeding. Mani (2008) states that sd1 gene is a gene which regulates the height of rice crops and is most widely used in plant breeding. That gene controls plant height stably in many different environments.

The best dry weight character of the stem was found in Banyuasin variety (2.01 g) but it was not significantly different from Balok accession and Inpago 8 variety. The high dry weight of the stems has an effect on lodging. According to Zuber (1994),the character of stem weight is phenotypically correlated positively to the level of lodging. The heavier dry rice stems are, the higher the lodging possibility is.

Heavy dry stems are caused by the chemical composition of the stem. Chemical composition is very influential on the lodging as well as the physical character of the plant. Hassan *et al.* (1992) states that the lodging resistance is also influenced by the chemical content of the plant stem. The chemical contents which can be found in stems are lignin and silica. Lignin and silica are the chemical components of the stem as the constituent of epidermal tissue function as plant props. Wang *et al.* (2014) states that the lignin concentrations contained in stem are very influential on the lodging resistance of the Buckwheat crop. Hasan *et al.* (1993) suggest that the increasing content of silica in short stem will increase the lodging resistance. Banyuasin variety is believed to have a high stem weight due to its high silica and lignin content compared to other genotypes.

The maximum number of tillers and productive characters was found in Banyuasin variety (27 and 20.9 stems). Generally, rice plants which have a large number of tillers have a short crown. Yahumri *et al.* (2016) states that plant height is negatively correlated with the number of productive tillers. Therefore, the higher the plant is, the lower the number of its productivity is. In addition, number of tillers is also affected by genotype. Li *et al.* (2003) states that the number of tillers is influenced by several genes in rice plants, such as the monoculm1 gene (MOC1) or fc1 which act as the regulator of tillers formation.

Inpago 4 variety has several characters associated with the level of lodging resistance. Inpago 4 variety had the largest stem diameter (6.72 mm) but not significantly different from other rice plant genotypes except Inpago 8 variety (Table 2). The larger diameter of the stem is expected to strengthen the plant which potentially have high yield, and have more lodging resistance. According to Fatimahrohman *et al.* (2016), the large diameter of the plant stem will make the plant more upright and strong. Inpago 4 variety has large diameter stem which is potentially to have lodging resistance.

Inpago 4 variety had a high percentage of pithy and low empty seed. The high percentage of pithy seed and low percentage of empty seed illustrate high yield potential. Inpago 4 variety had the highest percentage of pithy seed (73.95%) and the lowest empty seed percentage (26.05%) which was not different from Banyuasin variety and MP2046 mutant(Table 2). The percentage of empty and filled seeds can be affected by the lodgings factor. According to Koswara *et al.* (1985), the lodging state would potentially result in the disappearance of yield and the decrease of seed weight. Therefore, the genotype of rice plant which has lodging resistance character will be able to maintain high yield.

Inpago 4 variety also had heavier seed (28.01 mg), while Balok accession had the lowest seed weight (15.85 mg) (Table 2). The weight of the pithy seed is determined by the size of the seed and the weight of the food stock on the seed. Inpago 4, Banyuasin, Inpago 8, and MR1512 variety had larger seed size compared to Balok accession and MP2046 mutant. Nanlohy (2011) states that rice plant which has heavy seed, shows larger seed size. Seed size is influenced by the genotype character of the plant. Xing and Zhang (2010) states that the Aberrant Panicle Organization gene (APO1) affects the weight and the size of seed. Therefore, rice variety which has large seed such as Inpago 4 is believed to have heavier seed.

Inpago 8 variety had the greatest stem strength character and thick bark stem. The stem strength character is believed to be one of the factors affecting the lodging resistance. The stem strength of Inpago 8 variety (1583.3 g) was not different from the Balok accession (1301.8 g) and was significantly different from other genotypes (Table 2). The high strength of the stem causes the stem not be easily lodged. According to Keller (1998), the short rice crops which have large stem strength effects the high lodging resistance which goes along with linear regression (phenotypic variation = 77%). The thickness of the stem is also one of the characters affecting the strength of the stem. Inpago 8 variety and Balok accession had the highest stem bark thickness (0.12 mm) compared to other genotypes. According to Shiming and Gliessmen (2016), the thick stem is affected by vascular tissue and the thickness of epidermal tissue of the stem affecting the rate of lodging. Stem bark thickness of Inpago 8 variety and Balok accession is believed to have thick epidermal and vascular tissue.

Inpago 8 and Balok accession had very high canopy (120.42 cm) and height (150.52 cm). The scoring data showed that Inpago 8 variety had moderately high plant height (90-125 cm), while Balok accession was considered high (> 125 cm) (Table 2). This resulted in the plant becoming easily to lodge. According to Yamin and Moentono (2005), the lodging resistance is not due to the strength of the stem but due to the high character of the plant. This is supported by the statement of Chen *et al.* (2014) stating that plant height is the main factor causing plant to lodge. This statement is in line with the results indicating that although Inpago 8 and Balok accession had strong stem strength and thick stem, they had high canopy (> 120 cm) so that the plant was easy to lodge (more than 80% with score of 9). Based on these results it is suspected that the main factor affecting lodging is the height of the plant.

Inpago 8, Inpago 4, Banyuasin, and Balok accession had shed rate of 26-50% (score 7) (Table 2). High shed can result in yield loss during the harvesting process. Shed is caused by the gene causing shed, one of which is the shattering4 gene (sh4). Zhou *et al.* (2012) states that sh4 gene is a gene affecting the seed shed which is caused by differences in the abscission zone. Shedon the rice genotypes under the study is assumed to have sh4 genewhich causes high level of shed.

MP2046mutant had a short panicle character which has a positive impact to the lodging. The shortest panicle character was found in MP2046 (20.35 cm), which was not significantly different from MR1215mutant, Banyuasin and Balok accession, but significantly different from Inpago 4 variety. Permana (2010) states that rice having long panicle such as local accession has a high lodging susceptibility during the generative phase. This is presumably because the long panicle has a larger load so that the rice stem becomes curved and is easy to experience lodging.

The lodging condition of all rice plants genotypes are also influenced by internal and external factors. The internal factor that allegedly affects the lodging level is plant height. The scoring data (Table 2) showed that Banyuasin variety had short plant characteristic which resulted in plants having low level of lodging (score 1) and stem strength or straight stem (score 1). Other rice genotypes having good characters such as large stem diameter, stem strength and other characters were suspected to experience lodging due to high canopy (Table 2). The external factors also affect the lodging in form of wind and rainfall. *BMKG* data of 2017 shows that there was rainfall (48.5 mm) and a- 4 knots wind speed on May 8, 2017, resulting in most of the rice plants under study were in lodging state. This is consistent with FAO (2017) statement that the lodging plant is a state in which canopy fall on the soil surface due to strong winds, heavy rain, and high crops with thin stems and weak roots, resulting in curved stems and lodging.

MR1512 mutant rice genotype was then crossed with Banyuasin and Inpago 8 variety. The percentage of success between MR1512 and Banyuasin variety was 18.6%, and the crossing of MR1512 genotype with Inpago 8 was 51.5%. The crossings were then replanted to get the first generation (F1). The result obtained from the planting was 60 F1 furrows of red rice with growth percentage of 14.85%. The result of this crossing became the initial population for the lodging resistance of red rice.

CONCLUSION

Based on the results of research, it can be concluded that:

1. The upland rice with lodging resistance is characterized by short height (<90 cm) and supported by large dry weight stem, large stem diameter, and large stem strength.
2. Banyuasin variety is a genotype of rice plant which has a high lodging resistance character compared with other genotypes.
3. A total of 60 F1 red rice furrows have been obtained as the initial population of red rice with lodging resistance.

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