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Morphological and agronomical characters of four black rice varieties from West Kalimantan, Indonesia

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Abstract. *Palupi T, Pangaribuan F, Hearnes, Riyanto F, Wasian, Zulfita D. 2020. Morphological and agronomical characters of four black rice varieties from West Kalimantan, Indonesia. Biodiversitas 21: 1065-1073.* The black rice paddy is a variety of rice known to have anthocyanin content which is beneficial to human health. Yet, the black rice paddy is relatively rare to find as not all rice-growing areas develop and plant black rice. West Kalimantan has several potential black rice varieties which are potentials as genetic resources to create a new black rice variety in plant breeding programs. This research was aimed to describe the morphological and agronomical characteristics of four black rice varieties from West Kalimantan, namely Nanga Taman, Mukok, Senakin, and Ensalang. The study was conducted at the experimental garden of Agriculture Faculty, University of Tanjungpura, Pontianak using Completely Randomized Design. Each variety consisted of six replications, and each replication consisted of 3 samples. We observed 12 characters of the vegetative phase and 21 characters of the generative period. The four varieties had similarities in 13 characters and differences in 20 characters. The results showed that the four black rice had superior properties such as the stem angle and the angle of the leaves is upright so that it reduces interference from bird pests. Among them, the Senakin variety had an advantage over the three other varieties in terms of plant height, age, the number of productive tillers, and weight of grains.

Keywords: Characterization, genetic resources, paddy, plant breeding

INTRODUCTION

Indonesia has a large variety of genetic diversity of rice. One of them is black rice varieties. Differ with other varieties such as white rice and brown rice, black rice varieties are rarely documented, little known and under-utilized by society. Black rice is distinctively characterized by the color of pericarp, aleuron, and endosperm of thick red-blue-purple, indicating the presence of anthocyanin content. Black rice contains 7.16% protein, 0.25% fat, 28.46% fiber (Nurhidajah, 2018). Kristamtini et al. (2012) reported that the mineral content of black rice such as Fe, Zn, Mn, and P is higher than white rice, and that the mineral content in black rice depends on the variety and type of soil where it is grown.

Black rice varieties have not become a staple food like white rice, even though they have a higher nutritional value. One of the main reasons is black rice varieties have long period to harvest, making them have not been used optimally by the community. Nonetheless, black rice is potentials not only to fulfill food needs but can also help in maintaining health due to its anthocyanin substances. Black rice varieties have also potentially superior characters because most of them have adapted to environmental stresses when other common rice varieties have not (Agricultural Research and Development Agency, 2013).

Not all rice-growing areas have a large variety and have developed black rice. The utilization of black rice is started to be developed by several countries, including in Korea, because black rice is considered to be an essential part of maintaining health. In Indonesia, not many people know the existence of black rice despite the country have local varieties of black rice. In West Kalimantan, there are several locally known black rice varieties, among others are the varieties of Nanga Taman and Ensalang from Sekadau, Mukok from Sanggau, and Senakin from Landak. Yet, these varieties are difficult to find. Also, information regarding black rice in West Kalimantan is scant since there is limited effort to preserve the existence of black rice.

One initial step in the conservation and utilization of the diversity of genetic resources can be conducted through characterization. Characterization of local black rice varieties from West Kalimantan needs to done to understand the nature and characters of the plant so that it can be utilized the potential of the black rice. Until now, there is limited information regarding the morphological and agronomical description of black rice varieties from West Kalimantan. By carrying out characterization of the local black rice, data containing essential information about morphological characters (e.g. flower color, leaf shape, etc.) and its agronomical aspects (e.g. harvesting age, plant height, production, etc.) will be obtained. The purpose of this study was to investigate the morphological and agronomical characters of the vegetative and generative phases of four black rice varieties from West Kalimantan, namely Nanga Taman, Mukok, Senakin and Ensalang.

MATERIALS AND METHODS

Study period and location

The research was conducted from December 2016 to June 2017, at the experimental garden of Agriculture Faculty, University of Tanjungpura, Pontianak.

Experimental procedure

The experiment used Completely Randomized Design consisting of four treatments representing the varieties of black rice, namely A = Nanga Taman, B = Mukok, C = Senakin, D = Ensalang. Each treatment consisted of six replications with each replication consisted of three samples.

Black rice seeds used in this study came from farmers' harvests, from Sekadau (i.e. Nanga Taman and Ensalang), Sanggau (i.e. Mukok) and Landak (i.e. Senakin). The growing media consisted of red, yellow Podsolik soil mixed with fertilizer from cow manure in a ratio of 3:1 (v/v). Cow manure was added into a polybag two weeks before planting. The planting media was put into a polybag with a size of 40 x 50 cm. Seed planting was carried out by planting seeds directly on the prepared planting media. Before planting, the seeds were soaked for 1x24 hours. The floating seeds were discarded, then the sinking seeds were further soaked for 1x24 hours. Each polybag was planted with two seeds. After the seedlings grow, seedlings with better conditions among the two were selected and maintained.

Parameters observed

This research observed 12 characters of vegetative phase, i.e. the length and width of the leaf (measured was the leaf under the flag leaf in the flowering phase), blade pubescence (was done by touching the leaf surface from the top end to the base of the sheet), leaf angle (measured at the opening angle of the leaf tip to the stem, measured on the first leaf after the flag leaf), collar color, leaf sheath color, ligule color, blade color, and auricle color, ligule shape (observed at the tip of the leaf tongue, in the elongation of the stem phase), ligule length (measured from the base of the leaf neck to the tip of the leaf tongue, in the flowering stage), flag leaf angle (measured near the neck of the leaf, as the angle forms between the flag leaf and the main panicle shaft, in the flowering phase).

Twenty one of characters of generative phase were observed, i.e. culm strength (measured by carefully pushing the plants forward and backward several times, in the growth phase of the scale: 8-9), collapse (budsiness quantitatively expressed with percent of the number of plants that fall, at the growth phase scale: 6-9), plant height (measured from the base of the stem to the highest panicle tip and not including feathers, at the growth phase of the scale: 7-9), maturity (recorded in days from seedling to maturity, 85% of the panicles were ripened, in the growth phase scale: 9), number of productive tillers (observed after full flowering per plant, at the growth phase of the scale: 6-9), stem angle, panicle axis, and hair of the end of grain (in the growth phase of the scale: 7-9), internode color and leaf book (observed on the outer surface of the book, at the growth phase of the scale: 7-9), panicle length (measured from the neck to the tip of panicle, in the growth phase scale: 8), panicle type (classified according to the branching model, main branch angle, and grain density, at the scale of growth phase: 8), secondary panicle (in the growth phase of the scale: 8), grain per panicle (in the growth phase of the scale: 8), grain fertility (identified using fingers and recorded the number of full grain, measured at the growth phase of the scale: 9), color of the end of grain (in the growth phase of the scale: 6), grain length (measured from the bottom of the grain under sterile lemma to the end of the grain (apiculus) of lemma and palea fertil, in the growth phase of the scale: 9), grain width (measured as the widest distance between lemma and palea, in the growth phase of the scale: 9), 100–grains weight (100 puffed rice grains that was dried to 13% water content and weighed precisely in grams in the growth phase of the scale: 9), colors of lemma and palea (observed in the growth phase of the scale: 9), and presence of hair in the lemma and palea (visual observation of cooked grain using a magnifying glass, at the growth phase of the scale: 7-9).

Parameters analysis

Each observation parameter measured and observed was then recorded and analyzed using the classification codes or scales stated by the Institute for Agricultural Research and Development of the National Germplasm Commission, Ministry of Agriculture in the Guidelines for Rice Plant Characterization and Evaluation System (2003).

RESULTS AND DISCUSSION

The results of qualitative character observation showed that there were differences in ligule color, blade color, and auricle color, while the characters of blade pubescence, collar color, ligule shape, and leaf sheath color had no differences (Table 1).

The results of the observation on the characters of ligule color, blade color, and auricle color of Nanga Taman variety was different from the varieties of Mukok, Senakin, and Ensalang. These differences were marked with purple coloring on ligule color, blade color, and auricle color characters (Figures 1, 2, and 3).

The culm strength of the four black rice varieties from West Kalimantan was between moderate to rather strong (Table 2). The varieties of Mukok, Senakin, and Ensalang had similarities in culm strength, which were rather strong while the type of Nanga Taman was medium. The results of the collapse character were between 0 and 30.83%, with Nanga Taman had the highest density (30.83%), followed by Senakin variety (21.35%) whereas Mukok and Ensalang varieties did not have plants that fall, or the value of collapse was 0%.

The plant height of the four varieties was from moderate to high. High-sized varieties included Nanga Taman, Ensalang and Mukok, which were 160.93, 132.69 and 129.08 cm, respectively while Senakin had medium height (124.53 cm). There was difference in stem diameter

characters. The largest stem diameter was the Nanga Taman variety with 6.87 mm, followed by Senakin, Mukok and Ensalang with 6.71, 6.68 and 6.59 mm, respectively.

There was a variety in the period from planting to harvesting, ranging from 122-166 days or classified as long to very long period. Senakin had the age of 122 days after planting (long) while very long-lived varieties were Nanga Taman, Ensalang and Mukok, with 148, 157 and 166 days, respectively.

The number of productive tillers showed a difference between the four varieties, ranging from 12-21 tillers, or classified as medium to many. The highest number of productive tillers was produced by Senakin and Ensalang varieties with average of 21 tillers (many) and 18 tillers (medium), respectively. On the other hand, Mukok and Nanga Taman varieties had medium production of tillers with 13 and 12, respectively.

The observation of the character of the stem angle showed similarities, namely between 21-28° which is classified as upright. The Senakin had the largest stem angle with 28°, followed by Nanga Taman, Ensalang and Mukok with 23°, 22°, and 21°, respectively.

Table 1. Morphological and agronomical characters of the vegetative stage of four black rice varieties from West Kalimantan, Indonesia

Characters	Nanga Taman	Mukok	Senakin	Ensalang
Leaf length (cm)	69.67 (long)	81.99 (extra long)	61.54 (long)	66.02 (long)
Leaf width (cm)	1.79 (intermediate)	1.69 (intermediate)	1.57 (intermediate)	1.85 (intermediate)
Blade pubescence	Intermediate	Intermediate	Intermediate	Intermediate
Leaf angle (°)	27.17 (erect)	23.25 (erect)	25.41 (erect)	25.16 (erect)
Collar color	Light green	Light green	Light green	Light green
Leaf-sheath color	Green 143 B	Green 143 C	Green 143 B	Green 143 C
Ligule shape	2 –*Cleft*	2 – *Cleft*	2 – *Cleft*	2 – *Cleft*
Ligule length (cm)	1.83	2.13	2.19	1.94
Ligule color	Purple	Whitish	Whitish	Whitish
Flag leaf angle (°)	21.39 (erect)	22.61 (erect)	23.05 (erect)	25.28 (erect)
Blade color	Purple margins (085)	Dark green 137 B	Dark green 137 C	Dark green 137 C
Auricle color	Purple (080)	White	White	White

Note: The characterization followed to Guide of Characterization and Evaluation in the Rice Crop (IRRI, 2000) and Manual of Color by the Royal Horticultural Society

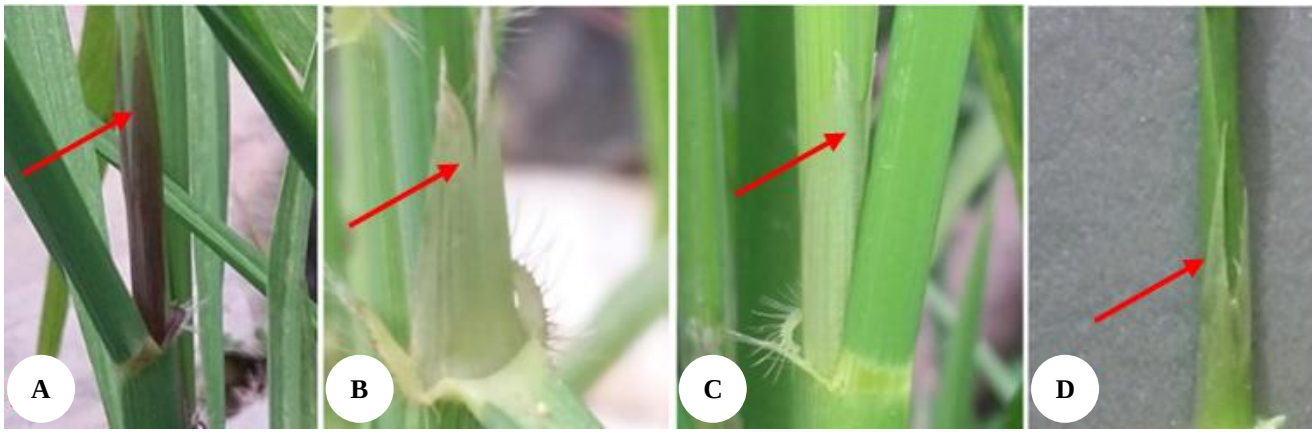

Figure 1. The ligule shape and ligule color of: A. Nanga Taman variety with 2-*cleft* and purple; B. Mukok with 2-*cleft* and white; C. Senakin with 2-*cleft* and white; D. Ensalang with 2-*cleft* and white

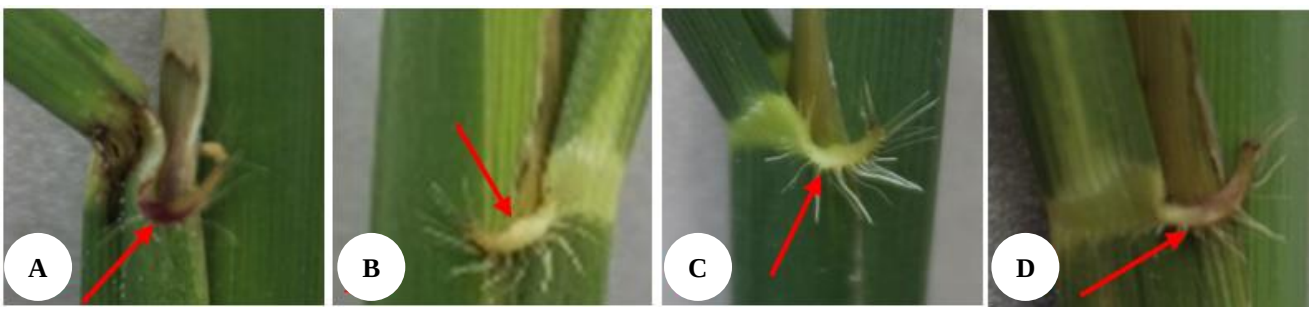

Figure 2. The auricle color of: A. Nanga Taman variety with purple line; B. Mukok; C. Senakin; D. Ensalang

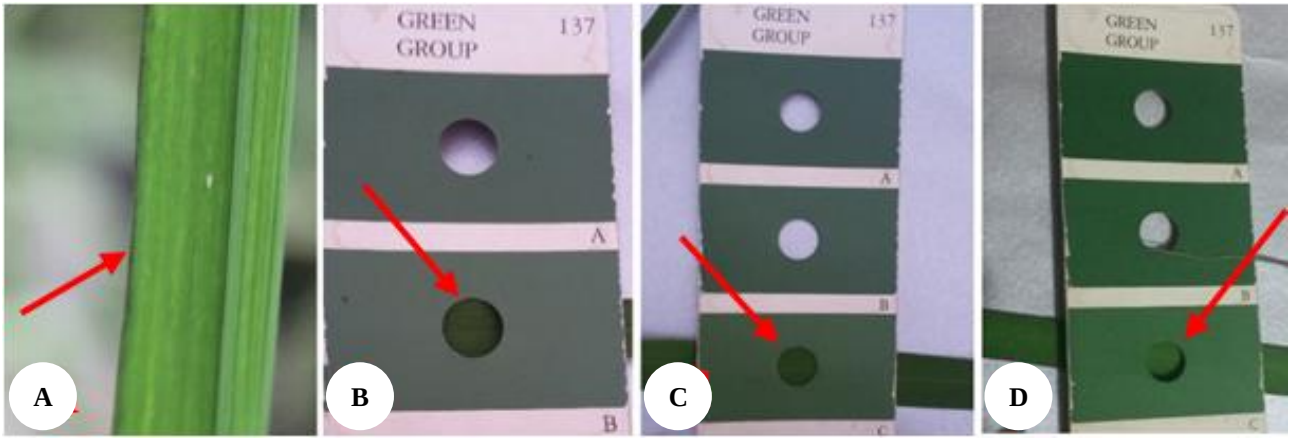

Figure 3. The blade color of: A. Nanga Taman variety with purple margins (085); B. Mukok with dark green 137 B; C. Senakin, and D. Ensalang both with dark green 137 C.

Table 2. Morphological and agronomical characters of the reproductive stage of four black rice varieties from West Kalimantan.

Characters	Nanga Taman	Mukok	Senakin	Ensalang
Culm strength	Intermediate	Moderately strong	Moderately strong	Moderately strong
Collapse (%)	31.12	0	21.35	0
Plant height (cm)	160.93 (high)	129.08 (high)	124.54 (moderate)	132.69 (high)
Maturity (date)	145 (extra long)	166 (extra long)	122 (long)	157 (extra long)
Number of productive tillers	12 (medium)	13 (medium)	21 (many)	18 (medium)
Stem angle (°)	23 (erect)	21 (erect)	28 (erect)	22 (erect)
Internode color	Green	Green	Green	Green
Leaf book color	Purple stripe	Green	Green	Green
Panicle axis	Floppy	Floppy	Floppy	Floppy
Panicle length (cm)	29.42	22.62	23.17	24.02
Panicle type	Medium and open	Between compact and medium	Medium	Between compact and medium
Secondary panicle	3-4 branches	3-4 branches	3-4 branches	2-3 branches
Grain per panicle	296 (many)	202 (many)	163 (medium)	233 (many)
Spikelet fertility (%)	83.28 (fertile)	77.81 (fertile)	75.11 (fertile)	81.87 (fertile)
Color of the end of the grain	Purple	White	White	White
Hair of the end of the grain	Absent	Absent	Absent	Absent
Grain length (mm)	9.21 (very long)	7.01 (long)	9.89 (very long)	7.46 (long)
Grain width (mm)	2.19	2.20	2.46	2.22
100 –grain weight (g)	2.04	1.31	2.27	1.40
Colors of lemma and palea	Yellow straw	Yellow straw	Brown lines on a yellow straw background	Yellow straw
Presence of hair in the lemma and palea	Short hairs	Short hairs	Short hairs	Short hairs

Note: The characterization followed to Guide of Characterization and Evaluation in the Rice Crop (IRRI, 2000) and Manual of Color by the Royal Horticultural Society.

The internode is the part of the main stem that is hollow. The observation of internode color of the four black rice varieties showed the same character, which was green. However, based on The Royal Horticultural Society Color Guidelines, the color characteristics of the internode has differences and similarities, which can be seen in Figure 4.

The leaf book is located between the leaf midrib and stem segments. The color of the leaf book observed was the outer surface of the book. The variety of Mukok, Senakin, and Ensalang had the same color, which was green, whereas Nanga Taman had purple stripe leaf color, indicating that this is capable of producing anthocyanins in leaf books. Based on The Royal Horticultural Society Color Guidelines, there are differences in the color of leaf books, which can be seen in Figure 5. The yellowing character of leaves in each black rice variety has the same category, namely medium or upper leaves yellowing.

There was no difference in the panicle because of the four observed black rice varieties having drooping panicle shaft. The character of panicle discharge in Nanga Taman and Mukok varieties had similarities, namely the whole panicle and neck out, while the Senakin and Ensalang

varieties had all medium panicles and medium neck. Axle and panicle discharge can be seen in Figure 6.

Observation on panicle length showed there were differences among varieties, ranging from 22.62 to 29.42 cm. The black rice variety that had the longest panicle was Nanga Taman with 29.42 cm followed by Ensalang, Senakin and Mukok varieties with panicle of 24.02, 23.17 and 22.62 cm, respectively.

The panicle type in the Mukok and Ensalang varieties had similarities between compact and medium. The Nanga Taman variety had a medium and open panicle type, while the Senakin variety had a medium panicle type. Panicle type can be seen in Figure 7.

Black rice varieties that had the highest number of secondary panicle branches were Nanga Taman, Mukok and Senakin with 3-4 branches of secondary panicles per panicle, while the Ensalang variety had 2-3 branches of secondary panicles per panicle or categorized as large or dense. The secondary panicle branch can be seen in Figure 8.

The highest number of grains per panicle was produced by Nanga Taman with 296 grains (many), followed by Ensalang, Mukok, and Senakin with the number of grains per panicle with 233 (many), 202 (many) and 163 (medium), respectively. Grains per panicle can be seen in Figure 9.

Grain fertility of all black rice varieties had similar category, which was fertile but it had different percentage values of spherical grain, ranging from 75.11-83.28%. Pitched rice can be seen in Figure 10.

The color of the tip of grain (apiculus) was generally white, as in the varieties of Mukok, Senakin, and Ensalang, but in the Nanga Taman variety, the color was purple. The purple color at the tip of the grain of the Nanga Taman variety indicated its capability of producing anthocyanin at this body part. The color of the tip of the grain can be seen in Figure 11.

Observation of the color of palea and lemma showed similarities in the varieties of Nanga Taman, Mukok and Ensalang, all had yellow straw. On the other hand, the lemma and palea in the Senakin variety had brown lines on a yellow straw background. The color of the lemma and palea can be seen in Figure 12.

Observation of the length of rice grain showed that the four varieties had long to very long rice grain. The most extended grain size was the Senakin variety with 9.89 mm (very long), followed Nanga Taman, Ensalang and Mukok with 9.21 mm (very long), 7.45 mm (long) and 7.01 mm (long), respectively. The grain width was between 2.19-2.46 mm with Senakin had the largest width (2.46 mm), followed by Ensalang, Mukok and Nanga Taman with 2.19, 2.21 and 2.22 mm, respectively. The grain size can be seen in Figure 14.

The observation of 100-grain weight showed that the Senakin variety had the highest weight with 2.27 grams, followed by Nanga Taman, Ensalang and Mukok with the respective weights of 2.04, 1.40 and 1.31 grams. All the four varieties showed a presence of short hair in the lemma and palea, and an absence of edge in the grain (Figure 13).

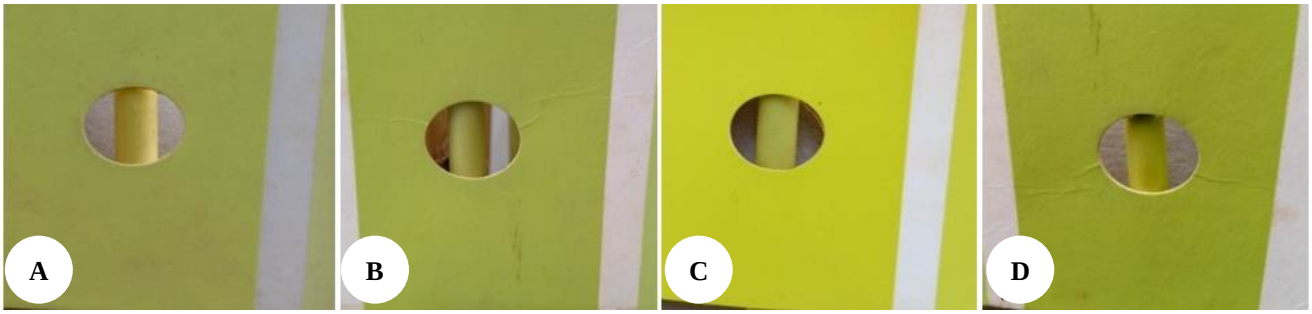

Figure 4. Color of internode based on the Color Guidelines *The Royal Horticultural Society*: A. Nanga Taman, *Yellow-Green Group* 145C; B. Mukok, *Yellow-Green Group* 145A; C. Senakin, *Yellow-Green Group* 145A; D. Ensalang, *Yellow-Green Group* 144C

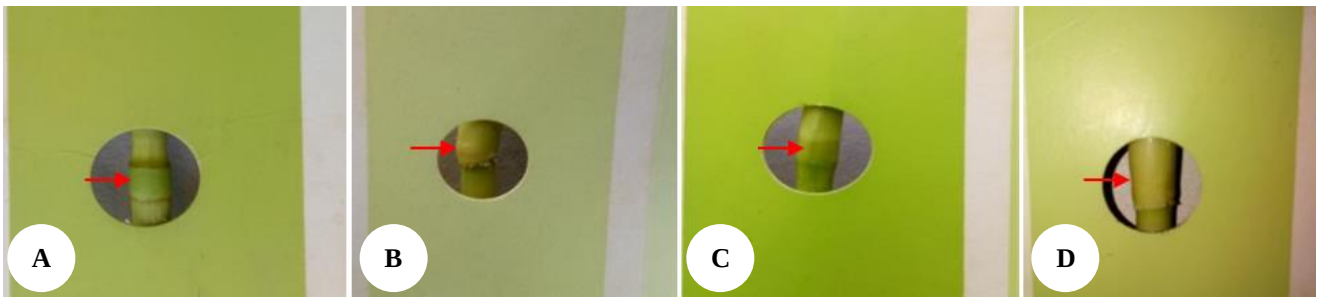

Figure 5. Color of the leaf book based on the Color Guidelines *The Royal Horticultural Society*: A. Nanga Taman, *Green Group* 145A; B. Mukok, *Yellow-Green Group* 145C; C. Senakin, *Yellow-Green Group* 144C; D. Ensalang, *Yellow-Green Group* 145B

Figure 6. Axle (a) and panicle discharge (b): A. Nanga Taman; B. Mukok; C. Senakin; D. Ensalang

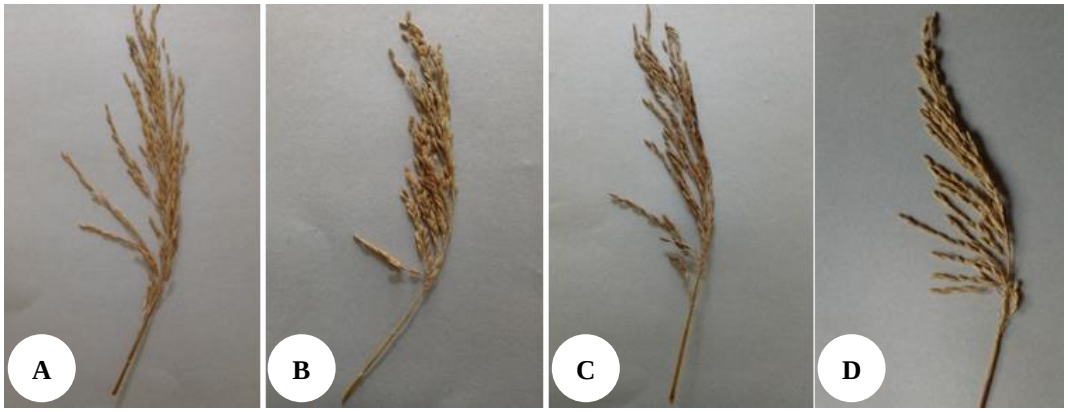

Figure 7. Panicle type: A. Nanga Taman (medium and open); B. Mukok (between compact and medium); C. Senakin (medium); D. Ensalang (compact and medium).

Figure 8. Secondary panicle branch: A. Nanga Taman; B. Mukok; C. Senakin; D. Ensalang

Figure 9. The grain per panicle: A. Nanga Taman; B. Mukok; C. Senakin; D. Ensalang

Figure 10. Grain: A. Nanga Taman; B. Mukok; C. Senakin; D. Ensalang.

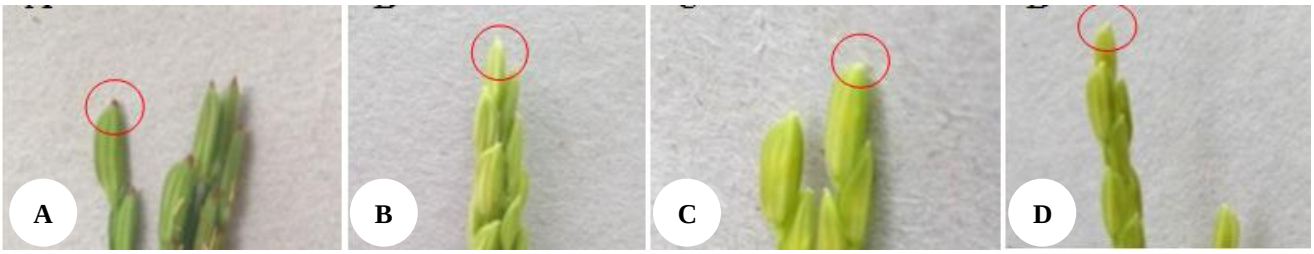

Figure 11. Color of grain tip: A. Nanga Taman; B. Mukok; C. Senakin; D. Ensalang

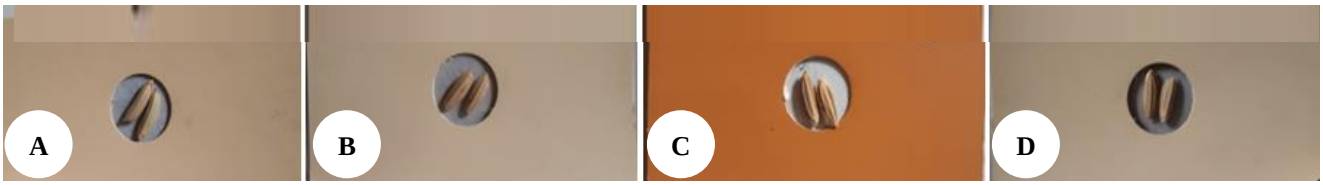

Figure 12. The colors of lemma and palea based on the Color Guidelines *The Royal Horticultural Society*: A. Nanga Taman, *Greyed-Orange Group* 165D; B. Mukok, *Greyed-Orange Group* 165D; C. Senakin, *Greyed-Orange Group* 165B; D. Ensalang, *Greyed-Orange Group* 165D.

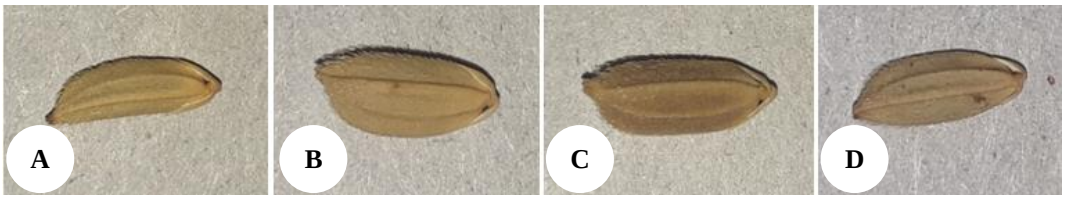

Figure 13. Presence of hair in lemma and palea: A. Nanga Taman; B. Mukok; C. Senakin; D. Ensalang.

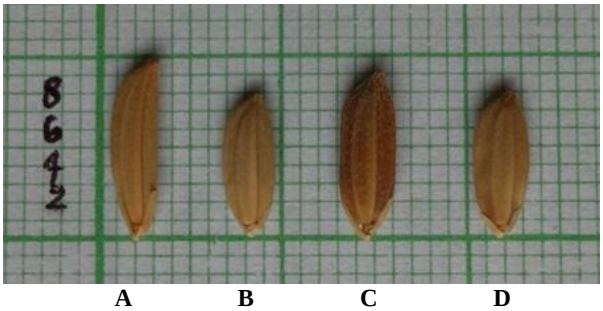

Figure 14. Grain size with milimeter block: A. Nanga Taman; B. Mukok; C. Senakin; D. Ensalang

Discussion

The results of the observation on the character of ligule color, blade color and auricle color of black rice Nanga Taman were different from the black rice paddy of Mukok, Senakin, and Ensalang in which Nanga Taman had purple color. The existence of this purple color is due to the ability of black rice Nanga Taman to produce anthocyanin and express it in its character. Sompong et. al. (2011) and Pengkumsri et al. (2015) said that anthocyanin is the dominant colored compound in black rice. For example, the magnitude of anthocyanin content may contribute to both

the color and the antioxidant activity found in each cultivar. Added by Aryana (2007), part of plant that contains anthocyanins will be reddish, purple to dark purple/black depending on their density. The ability of anthocyanin formation in each accession is different.

A rice variety can have similarities or different characteristics to other varieties. The similarities and differences in terms of morphological characters can be used to determine genetic relationship among black rice paddy varieties. Close relatives have many similarities between one another (Saputra, 2010). The more similarities between varieties, the closer the genetic relationship will be, while the more differences between types, the further the relationship will be.

According to Sahardi et al. (2013), one of the advantages of local rice varieties is that they have a high stem so that there is no need to bend when harvesting, making them are favored by farmers who still do harvesting traditionally. However, rice plants that have high stems can affect plant growth. High plants have a higher risk of falling compared to low height plants. Based on Framansyah (2014), taller plants have a greater burden than shorter plants so that higher plants have the potential to experience shedding. Rabara et al. (2014), rice plants that have a low plant height will reduce the level of lodging from these plants

Plant age is determined as the period from seedlings to harvest. Plant age can be divided into four classes, namely short, medium, long, and extra-long. According to Winarsih et al. (2017), one of the differences in plant age is influenced by the age of flowering. The longer the flowering period, the longer the harvest time. Putra et al. (2010), the shorters flowering age will be better because the plants are not excessive in the vegetative period, so the resulting product will increase.

Productive tillers are plants that are at juvenile stage produce panicles. The availability of sufficient nutrients at the time of growth will increase photosynthetic activity so that cell differentiation will be proper and cause the number of tillers to increase (Putih et al., 2011). Ogunbayo et al. (2014), the number of productive tillers was one of the factors affecting grain yield.

The observation of the character of the stem angle showed that the four varieties had similarities in stem angle, namely between 21-28° which is classified as upright. Knowing the angle of the plant stem can be used to determine the space of planting. Upright growth and erect leaves provide an opportunity for better light distribution (Vergara, 1995). The internode is the part of the main stem that is hollow. The observation of the color character of black rice paddy internode based on the characterization guidance system category, all had the same style, green.

The panicle length depends on the rice varieties planted (Setyono and Suparyono, 1993 in Putih et al., 2011). Varieties that have long panicles will produce a higher number of grains. The amount of grains per panicle depends on plant activity during the reproductive phase (Nugraheni, 2012). Observation of grain fertility is the result of a comparison between the amount of full grains per panicle with the total amount of grains per panicle. Vergara (1995) stated that the causes of grain void in plants include the fall of plants, low light intensity, disease attack, low temperature, and high humidity at the time of panicle formation and flowering.

The color of the tip of grain (apiculus) was generally white as in the varieties of Mukok, Senakin, and Ensalang, but in the Nanga Taman variety, the color was purple, indicating the presence of anthocyanins in this part (Aryana, 2007). Added by Lee (2010), Kang et al. (2011), and Yodmanee et al. (2011), the black rice paddy has a broad spectrum of seed colors that depend on many factors. The wide geographic distribution of black rice across both lowlands and highlands in Asia has led to environmental adaptations which lead to diversity among varieties and give each cultivar different morphological characteristics and phytochemical properties.

In conclusion, this study showed that four black rice varieties from West Kalimantan, namely Nanga Taman, Mukok, Senakin, and Ensalang, had superior properties such as the stem angle and the angle of the leaves is upright so that it reduces interference from bird pests. Among them, the Senakin variety had an advantage over the three other varieties in terms of plant height, age, the number of productive tillers, and weight of grains.

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