JURNAL

by Jurnal_pa Widi Buat Gb_5

BIODIVERSITAS
Volume 18, Number 3, July 2017
Pages: 1165-1172

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d180339

Yield-related traits characterization of local upland rice cultivars originated from East and North Kalimantan, Indonesia

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Manuscript received: 9 June. Revision accepted: 13 July 2017.

Abstract. *Nurhasanah, Sadaruddin, Sunaryo W. 2017. Yield-related traits characterization of local upland rice cultivars originated from East and North Kalimantan. Biodiversitas 18: 1165-1172.* In East and North Kalimantan, rice genetic diversities were very high. Most of the local rice cultivars existed in East and North Kalimantan, are upland rice cultivars. Unfortunately, most of those cultivars have not been optimally studied and characterized for rice breeding purposes. In this study, 146 upland rice cultivars originated from East and North Kalimantan were grown in the field which was further characterized their yield parameters. Tillering capacity, productive tiller, the size and structure of panicle as well as grain characteristics were characterized in the population to select potential superior cultivars. The results showed that the phenotypic variation of tillering capacity in those local upland rice was very high. Tiller number was varied from 2 to 66 tillers, with an average of 20.92 tillers and 25 cultivars had more than 30 tillers. Large range of productive tiller was also observed in the population, ranging from 14.8 to 100% of their tillering capacity, but most of the cultivars (80%) had more than 70% productive tiller. In addition, 9 cultivars had 100% productive tillers, in which all of the tillers generated panicles. Highly significant positive correlation (0.802**) was observed between productive tiller and tillering capacity. The panicle length of the local upland rice cultivars was in range from 14.5 cm to 43.5 cm, with most of the panicle size population clustered in length of 20-30 cm. In addition, 8.2% cultivars had a dense/heavy category, while 22.6% were sparse, and the rest of 70.2% had no panicle secondary branch. Variation of grain characteristics of local upland rice in the East and North Kalimantan including grain weight, grain length and width, as well as length-to-width ratio was also discussed in this study.

Keywords: East and North Kalimantan, local rice, upland rice, yield-related traits

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the top three leading food crops in the world together with wheat and maize. It is a staple food for more than half of world's total population. In Asia, rice is the most important cereal crops providing the main energy source of carbohydrates for most of the Asian people (Mohanty 2013). The trend of rice consumption apparently increases annually, even though it is varied in each country region. In the last two years, the number of global rice utilization is slightly higher than that of rice global production (FAO 2017). Therefore, efforts to increase the rice production are of importance to meet the high demand of rice in the market due to the vast population growth and future food security purposes.

The use of superior rice varieties is one of the most effective strategies to increase rice productivity together with the application of intensive cultivation techniques. As the most valuable factor in the successful rice-breeding program, the development of superior variety is not a rapid process in a short period. Several breeding strategies and procedures should be applied including genetic diversity exploitation in order to obtain the most promising germplasm candidates for the generation of new rice varieties.

Biodiversity plays an important role in plant breeding program. It provides genetic diversity as an important source in the generation of improved plant varieties. The presence of rice gene pool obtained from traditional/local, wild types and modern rice varieties, can maximize the availability of genes diversity. It becomes valuable gene repositories, which could be used for further important traits in rice breeding program. High genetic diversities of local rice cultivars have been successfully reported by Hendra et al (2009) and Nurhasanah and Sunaryo (2015). Furthermore, a large variation of several traits observed in the local rice population in East Kalimantan showed in the abundance of genetic variation (Nurhasanah et al. 2016). Wide geographical distribution and long history of cultivation may contribute to the great diversity and varied characteristics of local rice. According to Yawen et al. (2003) and Sarawgi and Bine (2007) the well-adapted local rice cultivars in a wide range of agro-ecological conditions may provide novel alleles, which potentially improve rice productivity and quality. Therefore, the local rice genetic diversity should be optimally used in rice breeding program.

Identification, selection, and evaluation of germplasms are the basic strategy of plant breeding programs. The identification of agronomical characters of germplasm is a primary activity in this study. This is an initial stage to discover potential parents for developing new superior rice variety. Therefore, the objective of this study was to characterize several yield traits of local upland rice germplasm from East and North Kalimantan for identifying the potential genotypes with superior characters for further used in breeding programs.

MATERIALS AND METHODS

Plant material

Plant materials used in this study were local rice cultivars originated from nine districts in East and North Kalimantan, Indonesia namely Penajam Paser Utara, Paser, Kutai Kartanegara, Kutai Barat, Kutai Timur, Berau, Malinau, Bulungan and Nunukan (Figure 1). One hundred forty six local upland rice cultivars consisted of 33 glutinous rice and 113 non-glutinous rice were observed in this study (Table 1).

Field trial

Field trial was conducted in Kutai Kartanegara Districts, East Kalimantan, from November 2015 to June 2016. The field experiment was done in randomized completely block designs (RCBD) with three replications. Each replication was assigned to one block, representing a homogeny environmental condition. The three blocks located in the same experimental location with a flat land contour was selected as the experimental area. Cultivation technique in this experiment was a modification of traditional upland rice cultivation generally applied by the local farmer. Intensive cultivation technique such as soil tillage, fertilization and liming as well as pest and disease control were applied.

Conventional soil tillage in a depth of 20 cm was conducted on the field after land clearing. Afterward, small plots of 3m x 3m (9m^2) were formed as beds. Organic fertilizer and calcite were applied in secondary tillage, two weeks before sowing in order to improve chemical, physical and biological soil condition and to reduce soil acidity. Three seeds were sown in every planting hole with a distance of 30 cm x 30 cm (distance between rows of hole). Thinning and replanting were carried out when the seedlings were two weeks old, to maintain only one seedling grown well in each hill. Rice plants were then treated according to general upland rice cultivation procedures. No daily watering procedures were applied in the field; it only depended on naturally water source (rainfall).

Agronomical characters and data analysis

Several agronomical characters of yield were observed, such as tillering capacity, productive tiller, panicle size and structure as well as grain characteristics. The traits were characterized based on descriptors for rice (*Oryza sativa*) procedure by IBPGR-IRRI Rice Advisory Committee (1980) and descriptors for wild and cultivated (*Oryza spp.*) (IRRI, 2007). Correlations between traits were carried out using Pearson correlation to analyze their relationship. Traits distribution was figured out in histograms. Simple statistical analysis, mean, minimum and maximum value, as well as standard deviation, were conducted for data analysis.

RESULTS AND DISCUSSION

Tillering capacity

For the improvement of potential yield, several trait identifications which may contribute significantly to increase rice yield potential are important to be done. It has been well known that tillering capacity is one of the most important characters determining yield potential, as it is closely related with the number of panicle per unit area. In this study, high variability of tillering capacity is observed in several local upland rice cultivars from East and North Kalimantan (Table 2). The tiller number of cultivars was in range of less than 10 or more than 50 tillers. Most of the cultivars (41.78%) had eleven to twenty tillers. Interestingly, one cultivar had more than sixty tillers, which belonged to non-glutinous rice cultivar.

Rice tiller is branch developed from the leaf axis on the unelongated basal internode, which grows independently of the mother stem (Yoshida, 1981). Tiller relates directly to the grain production in grass crops, since each tiller has the capacity to generate panicles. Many studies prior to understanding factors controlling and affecting the tillering capacity in rice in terms of genetics investigation (Li et al. 2003; Hussain et al. 2014; Uddin et al. 2016), and environmental factors (Assuero and Tognetti, 2009) have been conducted comprehensively. Genetically, tillering capacity is controlled by many genes (Yan et al. 1998; Miyamoto et al. 2004; Luo et al. 2012). One of quantitative traits characters is the continuous phenotypic variation, which could be seen from the distribution of tillering capacity in the local upland rice cultivars from East and North Kalimantan (Figure 2). Several environmental factors, such as the growth condition/cultivation methods (Kariali et al. 2014; Badshah et al. 2014), fertilizer (Zhong et al. 2002), light (Dingkuhn and Kropff, 1996), and temperature (Garba et al. 2007) affect the tillering capacity of rice. The abundance or limitation of those resources will increase or decrease the production of tillers. In this study, all environmental factors were in homogenous condition. Therefore, the varied results of tillering capacity achieved in the local upland rice cultivars from East and North Kalimantan should be caused by the genetic factor.

Table 1. East and North Kalimantan local upland rice population

Districts*	Number of rice cultivars	Glutinous rice	Non-glutinous rice
Penajam Paser Utara (E)	8	3	5
Paser (E)	17	6	11
Kutai Kartanegara (E)	21	2	19
Kutai Barat (E)	35	4	31
Kutai Timur (E)	19	5	14
Berau (E)	10	4	6
Malinau (N)	9	2	7
Bulungan (N)	11	4	7
Nunukan (N)	16	3	13
Total	146	33	113

Note: *Origin of plant material; (E) East Kalimantan Province; (N) North Kalimantan Province

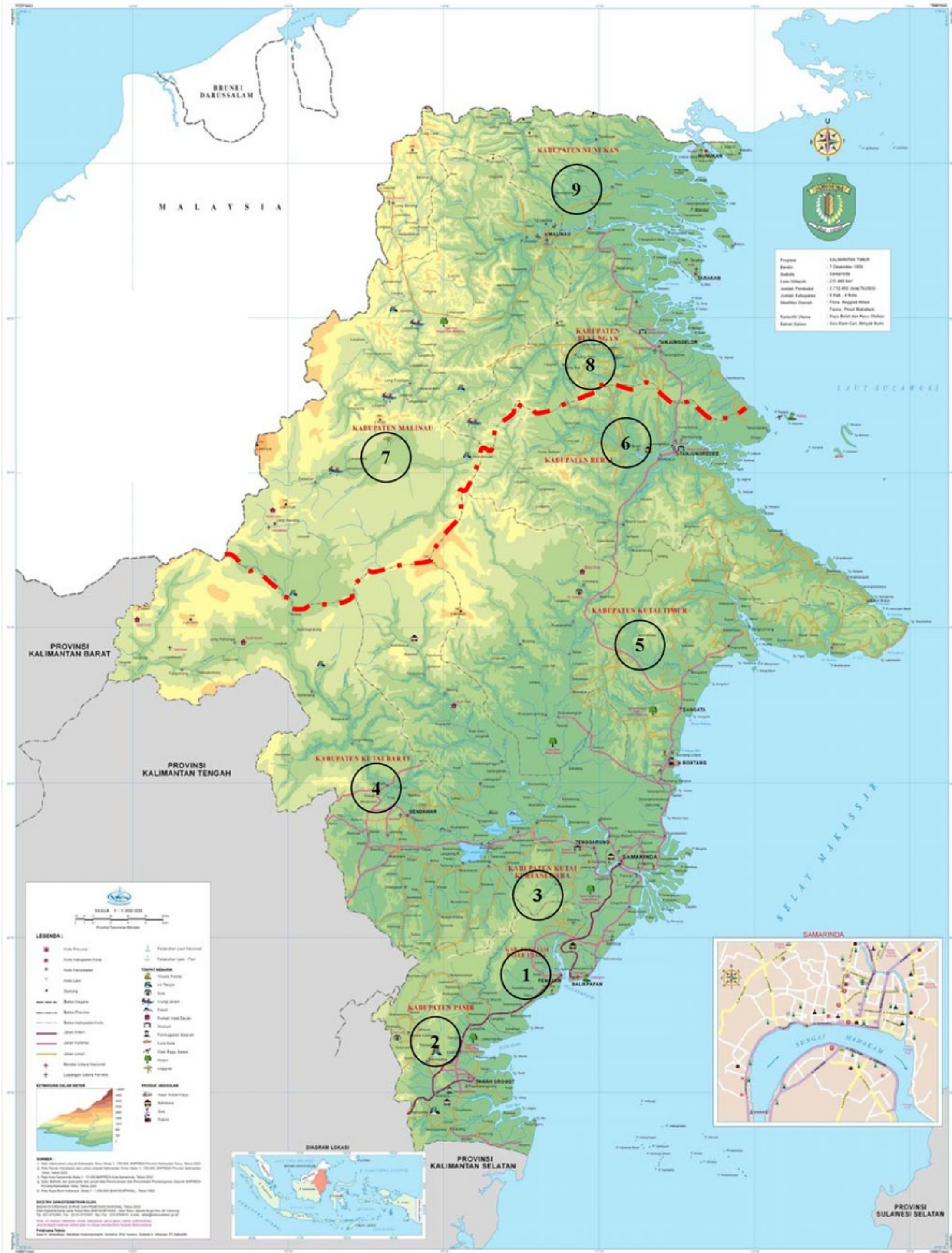

Figure 1. The origin of rice plant materials, East Kalimantan Province: 1. Penajam Paser Utara, 2. Paser, 3. Kutai Kartanegara, 4. Kutai Barat, 5. Kutai Timur, 6. Berau; North Kalimantan Province: 7. Malinau, 8. Bulungan, 9. Nunukan

Tillering capacity has influenced the rice productivity (Wang et al. 2007). High tiller number per plant is the most favorable characters as it is related to more panicle production. However, it will also increase plant density, which may lead to light and nutrient competition. In this case, tillers may not well develop or even die before they can produce a panicle. It will also cause uneven panicle maturity resulted in low grain quality in the harvest time. In addition, tiller producing no panicle or also called as unproductive tiller, is a competitor for the productive tiller. It reduces plant harvest index, and worthless agronomically as well as economically.

Nowadays, varieties with low tiller number are also categorized as new ideotype of rice. Low tiller number (three to four tillers when direct seeded) is one of criteria of new plant type (NPT) of rice besides another criteria such as few unproductive tillers, 200 to 250 grains per panicle, a plant height of 90 to 100 cm, thick and sturdy stems, dark green and erect leaves, a vigorous root system, 100-130 days growth duration, and increased harvest index (Peng et al. 1994). This new ideotype of rice is claimed effective for breaking the yield. A superior rice variety could be improved by increasing yield potential with the reduction of tillering capacity to a large panicle size (Peng et al. 2008). The NPT China's "super" hybrid rice, for example, produced grain yield of 12 ton ha^{-1} on trail fields, which is 8 to 15% higher than the hybrid model varieties. In addition to large panicle size, the increased yield through high-density grains was also considered as one of the impacts of low tiller number in rice (Vergara et al. 1990).

Productive tiller

Productive tiller is a very important yield traits because the final yield is mainly a function of the number of panicles bearing tillers per unit area. Results showed the productive tiller observed in the East and North Kalimantan upland rice population (Table 4) was in large range from 14.8 to 100%. Around eighty percent of the cultivars in the population had more than 70% productive tiller. Remarkably, twenty percent of the cultivars had productive tiller of more than 90% of their tillering capacity.

A high tillering capacity cultivar as 'Siam' had 66 tillers and around eighty percent of the tillers were productive. Meanwhile, 'Umbung Kirip' cultivar with low tillering capacity (6.5 tillers) had only 50% productive tiller (3.5 panicle bearing tillers). The lowest percentage of productive tiller in the population was observed in 'Rendah Kuning' cultivar. This cultivar had 47.3 tillers, and only fifteen percent of them were panicle-bearing tillers. Interestingly, there were nine cultivars in the East and North Kalimantan upland rice population having 100% productive tiller, meaning that all of the tillers generated panicles. These cultivars consisted of low to high tillering capacity cultivars (Table 5) ranging from 10 to 30 tillers.

High productive tiller number is one of the important criteria in rice, either in varieties with high or low tillering capacity. Some superior rice varieties that have been released in Indonesia have tiller number less than ten, but the varieties have high productive tiller. As an example, 'Fatmawati' which is one of superior new plant type (NPT) rice variety in Indonesia has a potential yield of 9 ton ha^{-1}. Interestingly it only consisted of 8 to 14 tillers (Suprihatno et al. 2009) but most of them were productive.

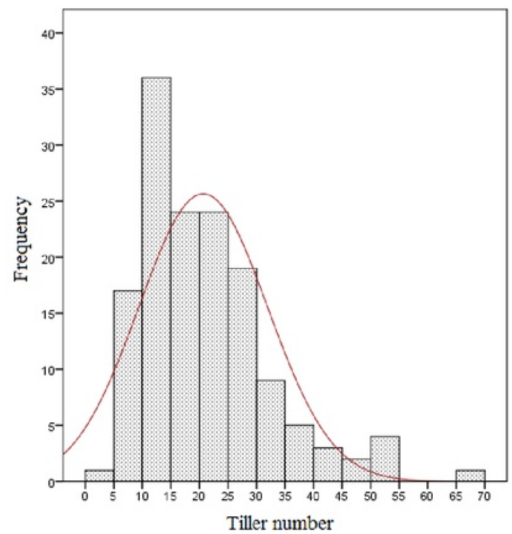

Figure 2. Tillering capacity distribution in East and North Kalimantan, Indonesia local upland rice population

Table 2. Tiller number of East and North Kalimantan, Indonesia upland rice

Tiller number	Frequency	Percentage
0-10	19	13.01
11-20	61	41.78
21-30	41	28.08
31-40	14	9.59
41-50	8	5.48
51-60	2	1.37
> 60	1	0.68

Table 3. The percentage of productive tiller produced in observed cultivars from East and North Kalimantan, Indonesia upland rice

Percentage of productive tiller	Percentage of cultivar
0-10	0.00
11-20	0.93
21-30	2.78
31-40	0.93
41-50	2.78
51-60	6.48
61-70	6.48
71-80	24.07
81-90	34.26
91-100	21.30

Table 4. Cultivars having 100% productive tillers

Cultivar	Origin/ District	Type of Rice
Sebuyung Biasa	Paser	Non-glutinous
Sebuyung Harum	Paser	Non-glutinous
Ketan Serang*	Paser	Glutinous
Ketan Tangkai Ngeno	Paser	Glutinous
Siam Putih	Penajam Paser Utara	Non-glutinous
Bogor Gemuk	Kutai Barat	Non-glutinous
Ketan Hitam	Berau	Glutinous
Ketan Sed	Bulungan	Glutinous
Padi Ulin	Malinau	Non-glutinous

Note: *Ketan is the name for sticky (glutinous) rice in Indonesia

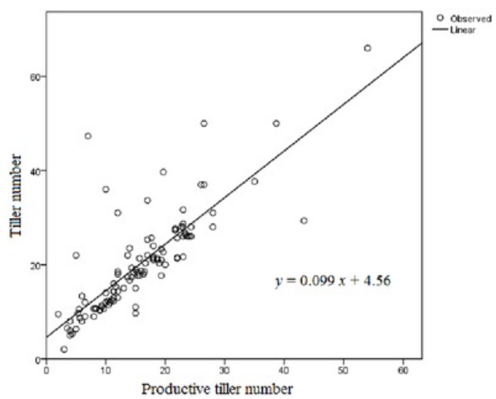

Figure 3. Relationship between tiller number and productive tiller number of all observed cultivars

In a previous study, Badshah et al (2014) observed that the higher tiller number, the higher senescence tillers, unwell developed or died tillers before they can produce panicles. It means that low tiller number might generate high panicle-bearing tiller rate rather than the high tiller. Furthermore, Huang et al. (2011) explained that excessive tiller number leads to high tiller abortion, poor grain setting, small panicle size, resulting in further reduced-grain yield. Contrary to those results, a highly significant correlation between tillering capacity and productive tiller (R=0.802**) was obtained in this study, indicating that the higher the tillering capacity, the higher the productive tiller number (Figure 3).

Panicle size and structure

The size and structure of panicles are important factors contributing to both yield and rice quality (Yamagishi et al. 2003; Mo et al. 2012). Therefore, rice variety with increasing panicle size and weight is considered as a potential high yield variety. Large variation was observed in the panicle size of East and North Kalimantan local upland rice population. The panicle length distributed from 14.5 cm to 43.5 cm (Figure 4, Table 5). Most of the panicle size in the population clustered in the 20-30 cm length with the mean value of 25.3 ± 4.2 cm (Mean ± SD).

Panicle length, representing the panicle architecture, is one of the important yield-related traits. It is categorized as a quantitative trait, which is controlled by many genes (Liu et al., 2011; Yao et al., 2015). It has high phenotypic variation and largely influenced by environmental conditions. High phenotypic variation of panicle length is not only observed amongst rice species but also within rice subspecies. Generally, subspecies *indica* has longer panicle length than *japonica*. According to Zuo et al (2014), a considerable genetic variation of panicle length could happen within subspecies, which was also observed in this study.

Panicle secondary branching is one of qualitative character that could also contribute to panicle size and weight. There are several types of secondary branches of panicle in rice description, dense/heavy, sparse/light or absent. In the North and East Kalimantan, the cultivars of local upland rice population consisted of 11 cultivars (8.2%) having dense/heavy panicle secondary branches and 33 cultivars having sparse, and around 70% of the cultivars in the population have no secondary branch. It means that the eleven cultivars (Table 6) with a dense panicle secondary branch might be used as promising rice germplasm for high yield varieties. In a study conducted by Mo et al (2012), highly positive correlations (>0.95) between secondary rachis-branches and spikelets number per panicle has been reported. In addition, a higher number of spikelets was obtained in secondary rachis-branches per panicle compared to that in primary rachis-branches. These results were observed either in rice type of *japonica* or *indica* (tongil type), cultivated in both of different cultivation conditions, i.e. greenhouse and in the field. In this study, we did not calculate the number of spikelets per panicle, but we predict that the cultivars with a dense panicle secondary branches might produce a higher number of spikelets resulted in high yield production.

Grain characteristic

Grain characteristics are a component that can vary depending on the rice variety. In this study, variation was observed in grain characteristic of East and North Kalimantan upland rice cultivars. It could be seen from the grain weight, grain length and width, as well as length-to-width ratio characters (Table 7). The variation could also be clearly observed from the distribution of the traits in the population (Figure 5). Most of quantitative traits exhibited continuous distribution which could be seen in rice grain characteristics. Several studies have confirmed that grain weight, grain length and width, and length-to-width ratio are quantitative traits, which genetically controlled by several genes (Lin and Wu 2003; Fan et al. 2006; Huang et al. 2012; Wang et al. 2012).

Grain weight, which is normally characterized by weight of thousand seeds, is one of the major components determining grain yield in rice (Xing and Zhang 2010), besides another component including number of panicles per plant and number of grains per panicle. It could give information about the density and size of the rice grains. Therefore, this trait cannot be separated from grain length and grain width, since they have a positive correlation with each other, although the grain length may give more contribution to the grain weight than the grain width (Lin and Wu 2003). Furthermore, both grain length and width also influence grain characteristics of rice. The comparison between grain length and width will determine the shape of rice grain. Approximately three-quarter of the local rice cultivars have slender/long grain shape, and the rest one-quarter have bold grain shape (Table 8). None of the cultivars have round or short grain shape based on FAO scale standard of length/width comparison.

Grain size and shape are important components of grain yield and quality. These characteristics have been considered as one of important selection criteria in rice breeding for the development of new varieties. They have a major impact not only on rice yield but also in the market values of rice grain products. Grain size and shape can directly affect consumer preference and choice, although the preference may vary from one ethnic to others. In addition, grain shape is also associated with certain cooking and processing characteristics. Most long-grain varieties tend to become dry and fluffy when it is cooked and the cooked kernels do not split or stick together. Short-grain varieties are usually more cohesive and firm than long-grain varieties. Medium-grain varieties generally have intermediate features. Nevertheless, those cooking and processing characteristics actually happen due to inherent differences in chemical properties of the starchy endosperm (Cruz and Khush 2000; Oko et al. 2012) rather than because of the grain shape.

In conclusion, there were several potential yield-related characters in upland rice cultivars originated from East and North Kalimantan, i.e. high productive tillers number, large panicle size and structure, and large preference of grain characteristics. Some of the upland rice cultivars carrying the desired yield-related traits could be further used in rice breeding programs for developing new superior varieties of upland rice with high yield potentials.

Table 5. Length of panicle of upland rice cultivars originated from East and North Kalimantan, Indonesia

Panicle length	Frequency	Percentage
10-15	1	0.68
16-20	12	8.22
21-25	56	38.36
26-30	62	42.47
31-35	12	8.22
36-40	1	0.68
41-45	1	0.68

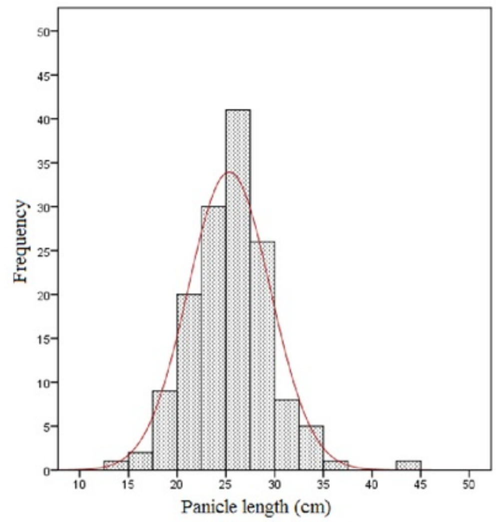

Figure 4. Panicle length distribution of upland rice population in East and North Kalimantan, Indonesia

Table 6. Cultivars possessing a dense panicle secondary branches

Cultivar	Origin/District	Type of rice
Mayas Pancing	Kutai Kartanegara	Non-glutinous
Mayas Kuning	Kutai Barat	Non-glutinous
Mayas Sereh	Kutai Barat	Non-glutinous
Arum	Kutai Barat	Non-glutinous
Baqu'	Kutai Barat	Non-glutinous
Telion	Paser	Non-glutinous
Ketan Tangkai Ngeno	Paser	Glutinous
Geragai	Paser	Non-glutinous
Sungkai	Penajam Paser Utara	Non-glutinous
Sereh	Penajam Paser Utara	Non-glutinous
Dupa	Penajam Paser Utara	Non-glutinous

Table 7. Grain characteristic of upland rice originated from East and North Kalimantan, Indonesia

Grain characteristic	Min.	Max.	Mean	SD
Grain weight (gram)*	0.13	0.47	0.25	0.06
Grain length (mm)	6.82	10.93	8.57	0.78
Grain width (culm)	1.60	3.80	2.58	0.38
Grain length/width	2.13	5.81	3.40	0.61

Note: *Weight of 10 seeds

Table 8. Grain shape characters of upland rice originated from East and North Kalimantan, Indonesia

Grain shape (length/width)	FAO scale (mm)	Frequency	Percentage
Slender (long)	Over 3	110	75.34
Bold	2.0-3.0	36	24.66
Round (short)	Less than 2.0	0	0

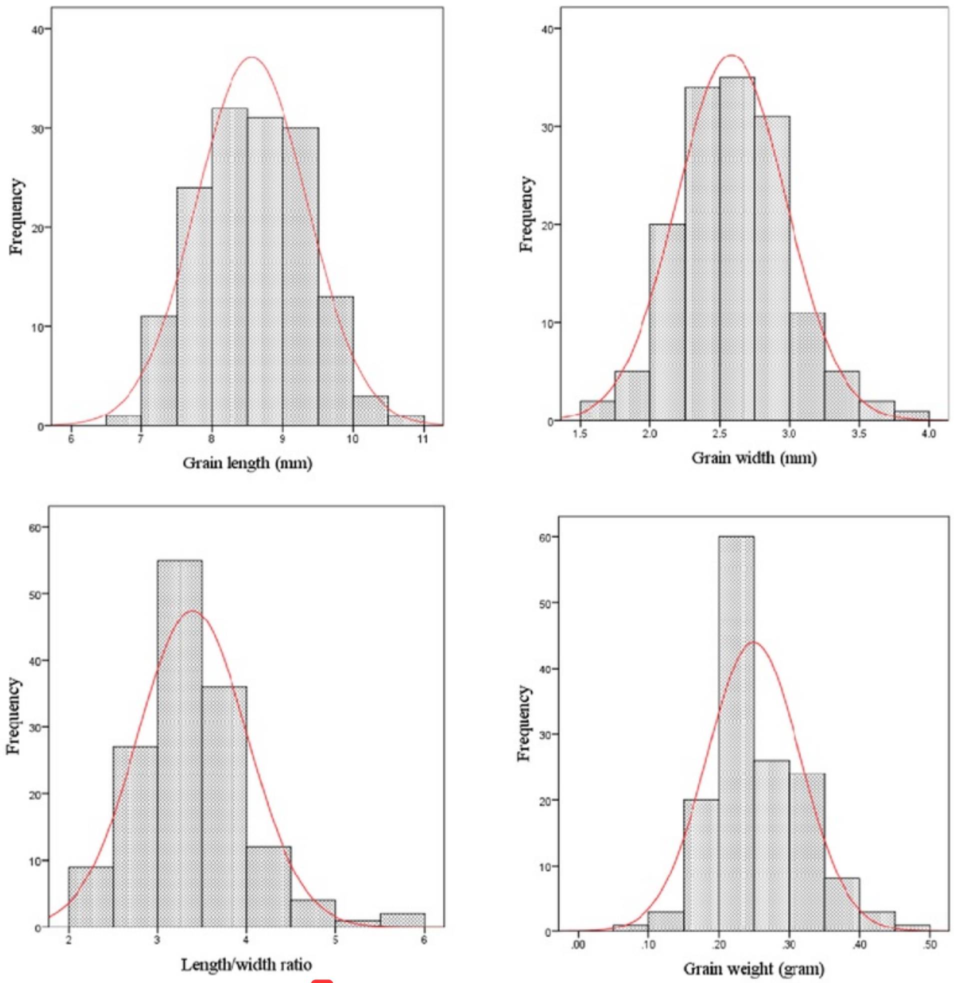

Figure 5. Grain characteristic traits distribution in East and North Kalimantan, Indonesia local upland rice population

ACKNOWLEDGEMENTS

This study was funded by INSINAS Grant 2016 (RT-2016-0569) Ministry of Research, Technology and High Education, Government of Indonesia to which authors are highly indebted.

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