Characterization of five local varieties of rice (*Oryza sativa* L.) in east java, Indonesia

Characterization of five local varieties of rice (*Oryza sativa* L.) in east java, Indonesia

Dwi Rahmawati*, Putri Santika, Divanda Rifka Ramadhan Fauzi, dan Moch Rosyadi Adnan

Department of Agricultural Production, State Polytechnic of Jember

rahmawati@polije.ac.id

Abstract. Some regions in Indonesia, especially East Java, have abundant local varieties of rice. However, these germplasms have not been optimally developed in plant breeding. Characterization ranked as the first step in plant breeding to identify morphological and agronomic characteristics of the germplasms. This study aims to characterize several local rice varieties in East Java, including 'Ketan Genjah' (V1), 'PIM' (V2), 'Pendok' (V3), 'Padi Hitam' (V4), and 'Padi Merah' (V5) to point out each strength in several parameters to be used as a potential gene source for plant breeding. The results of this study indicated that the varieties studied have several distinct morphological and agronomic characters with each other. In terms of plant height, leaf length, pithy grain percentage, grain loss percentage, and the weight of 1000 grain, 'Pendok' showed superiorities compared to other varieties. In addition, 'Pendok' also had the highest yield per clump together with 'Ketan Genjah' at 151.32 g and 150.82 g, respectively. 'PIM' had the longest panicle length, whereas in terms of number of tillers, 'Ketan Genjah', 'Padi Hitam', and 'Padi Merah' were the highest among the varieties studied.

1. Introduction

Standing among vital food crops in the world, rice (*Oryza sativa* L.) remains consumed as the staple food for most populations in the world, especially in Asia. In Indonesia, rice stands as the most widely cultivated and developed commodity [1]

In Indonesia, there are three types of rice based on the coloration of the rice. The three are black rice, red rice, and white rice. Black rice is one of the traditional rice varieties which is richer in micro and macronutrients, amino acids, phytochemicals, secondary metabolites, and anthocyanin content [2]. Red rice is also reported to have low carbohydrate content, high amino acids, protein, and anthocyanin [3] and low Glycemic Index (GI) [4]. Thus, black rice and red rice are believed to give better health properties compared to white rice. As the awareness of a healthy lifestyle is growing, black and red rice is becoming more popular. However, among the three types of rice, the most widely grown and consumed in Indonesia is white rice, for its better taste [5].

Prior to the Green Revolution in the 1970s, in which farmers were introduced to some new superior foreign varieties from IRRI, farmers in each region grew local rice that was specific to each agroecosystem. Some regions in Indonesia, especially East Java, have abundant local rice varieties. According to Sitaresmi et al. [6], local varieties have been cultivated for centuries and from generation to generation. For centuries, these local varieties are able to withstand changes in the ecosystem and are able to adapt well.

In terms of productivity, local rice varieties might seem as inferior to the newer introduced superior varieties. However, these local rice varieties also have the potential as germplasm resources and various beneficial gene donors in plant breeding programs. Several local varieties predictably have a higher adaptability, higher resistance to pests and diseases as well as lower grain loss and empty grain [7]. In addition, rice biodiversity is a very valuable asset for the assembly and improvement of rice varieties

and their preservation [8]. The International Rice Research Institute (IRRI) is still making efforts to develop rice crops, which has recorded the preservation of more than 106,800 rice accessions in the IRRI Gene Bank in the Philippines [9]. Furthermore, it is important to collect and record all data regarding local rice varieties the valuable assets for future studies.

In East Java, Indonesia, there are some well-known local rice varieties, such as 'Ketan Genjah', 'PIM', 'Pendok', 'Padi Hitam', and 'Padi Merah'. 'Ketan Genjah' is known for its high content of gluten and early maturity. 'PIM' is known for its giant stature that can reach up to 2 meters and has high resistance to pests. 'Pendok' is famous for its aroma and delicious taste. 'Padi Hitam' is a black rice variety, whereas 'Padi Merah' is a red rice variety. These local varieties, however, have not been optimally developed in plant breeding as potential gene sources. Thus, the current study aims to characterize morphological and agronomical characteristics of several local rice varieties in East Java, as an initial step in the plant breeding program.

2. Implementation Method

This research took place in the Experimental Field of the Agricultural Production Department of the State Polytechnic of Jember. The experiment was performed using a non-factorial Randomized Block Design. The varieties observed consisted of: 'Ketan Genjah' (V1) from Nganjuk, 'PIM' (V2) from Blitar, 'Pendok' (V3) from Tuban, 'Padi Hitam' (V4) from Tulungagung, and 'Padi Merah' (V5) from Malang. These varieties were grown in the field and observed in several morphological and agronomic traits. The data obtained from the research were statistically analyzed using Analysis of Variance (ANOVA) and further tested with Duncan's Multiple Rate Test (DMRT) at $P<0.05$.

3. Experimentation

Planting took place at greenhouse which has been cleaned 2 weeks prior to planting. The soil used for planting media was ultisol type originating from dry land in Ambulu area. Weighing 10 kg of soil in each polybag, water was supplemented to make the moisture level 20% with approximately 12.5 kg of weight. Cow manure was subsequently added as organic fertilizer into the soil with the approximate weight of manure (including its water content at 65%) at 28.5 tons/ha (c.a. 142.9 g/polybag). The size of the polybag used for planting was 30 in diameter and the height of planting media was 25 cm.

Prior to starting planting, rice seeds were immersed in water for 24 h a day before seeding. Afterward, imbibed rice seeds were sown in a small tray with the media consisting of soil and manure mixed with a ratio of 1:1 and grown for 2 weeks. After 2 weeks, the growing seedling is then placed into polybags. During the cultivation, basic fertilizer NPK was added (150 kg/ha ~ 0.8 g/ polybag) with addition at 3 weeks and 5 weeks old after planting. Water was added to the media until it reaches its saturation point. Weeds were regularly removed manually to avoid competition with the main plants. In addition, insecticide and fungicide 500 g/l BPMC and 250 g/l of Difenoconazole fungicides were added to control insect and fungus pests. Additionally, a net was also provided to prevent bird attacks. The harvesting phase was indicated by panicle ducking, the maximum hardness of the grain, the panicle stems turned yellow, and 95% of the grain turned yellow as well.

3.1 Observed Variables

a. Qualitative Variable

1. Grain

i. Type : determined after harvest, and the type were cere' or hairy,
ii. Color : determined after harvest, and the type were straw yellow, golden yellow, red or purple
iii. Shape : determined after harvest, and the type were slender, medium, oval, or round
iv. Loss : determined after harvest by grasping the harvested panicles and

comparing the number of unhulled grains and total number of seeds per panicle. The types were; difficult (<1%), rather difficult (1-5%), moderate (6-25%), rather easy (26-50%), or easy (51 - 100%).

2. Stem color : determined during mature stage, the types were green, golden yellow, purple striped, and purple.
3. Plant :
   i. Plant shape : determined after plants and grain reach complete maturity, the types were upright (<30^{O}), moderate (+45^{O}), open (+60^{O}), and scattered (>60^{O}).
   ii. Position of flag leaf: determined in the primordia phase. The types were upright, medium (± 45^{O}), horizontal, or drooping
4. Leaf :
   i. Surfaces : determined during flowering phase, the types were hairy, medium, and hairless
   ii. Color : determined during mature stage, the types were light green, green, dark green, purple at the tip, purple at the edges, and a mixture of purple with green, or purple
   iii. Foot color : determined during flowering phase, the types were green, striped purple, light purple, or purple
   iv. Tongue color : determined during primordia phase, the types were white, purple stripped, or purple
   v. Ear color : determined during primordia phase, the types were white (no color), striped purple, or purple

b. Quantitative Variable

1. Plant height (cm) : determined during harvest, by measuring the length of base stem to first ring at highest panicle
2. Number of tillers (stems): determined during primordial phase, by counting all growing Tiller
3. Number of productive tillers (stems) : determined during mature phase, by counting all panicles-producing tillers per clump.
4. Flowering age (days) : determined during primordial phase, by counting the number of days from planting to the initiation of flowering
5. Age of harvest (days) : determined during mature phase, by counting the number of days from planting to the ducking of panicles when the grain reach maximum hardness, and 95% of the grain has turned yellow.
6. Panicle length (cm) : determined during harvest phase, by measured the length upon harvest from the first ring on the panicle to the tip of the panicle. The measurements took 5 panicles sampled randomly from each plant.
7. Number of grains per panicle (grain): determined during harvest phase, by counting the number of empty and pithy grains from each panicle after harvest. Observations were made on 5 panicles which were used to measure panicle length.
8. Percentage of pithy grain (%): determined during harvest phase, by counting and comparing the number of pithy grains and the total number of grains in plants
9. Weight of 1000 seeds (g): determined during harvest phase, by counting 1000 milled dry grain (± 12% moisture content) after harvest

10. Yield per clump (g) : determined during harvest phase, by weighing all paddy grain in 1 clump after harvest.

4. Result and Discussion

Morphological traits

The summary of morphological traits of the five local varieties is presented below in Table 1. In terms of morphological traits, there are a few similar traits between each other, although there are some distinctive features as well. While the other four varieties have quite similar colors of a ligule, leaf blade, leaf sheath, auricle, stigma, lemma, and palea, 'Padi Merah' seemed to be the most distinct. Qualitative characters are usually influenced by one or several genes. Qualitative traits commonly are slightly influenced by environmental cues and their phenotypes are predominantly governed by less complex genes [10]. Nevertheless, as with other traits, morphological and agronomical character of a plant is a sum of genetic effect, environmental effect, and the interaction effect between the two [11].

Other than the colors, the most visible different features were grain shapes, flag leaf angle, and panicle type. 'PIM' and 'Pendok' have round grains, whereas 'Ketan Genjah', 'Padi Merah', and 'Padi Hitam' have lean types of grains. Grain shape and its component (length, width, and ratio) is considered as a significant indicator of quality and consequently attributes to grain weight and nutritional quality [12]. In Indonesia, lean grain is preferred because of its fluffier and more delicious taste [13].

'Pendok' and 'Padi Hitam' had the widest flag leaf angle with more than 90, whereas 'Ketan Genjah' and 'Padi Merah' had the narrowest flag leaf angle with less than 45. Plants with wider canopy have more chances to have better light and CO2 uptake [14]. However, a wider canopy could also need a wider planting distance to avoid light and CO2 competition and avoid higher chances of diseases.

In terms of leaf surface, all of the local varieties observed were hairless. Leaf surface presumably has a close relationship with resistance to leaf blight diseases of which the more hairless the surface, the lower the chance of the diseases [15]. Other findings also explained that some phenotypic traits indeed have a relationship with sheath blight resistance in rice [16].

Table 1. The summary of morphological traits of the five local varieties

Morphological traits	Local Rice Variety				
	(V1) 'Ketan Genjah'	(V2) 'PIM'	(V3) 'Pendok'	(V4) 'Padi Hitam'	(V5) 'Padi Merah'
Ligule color	White	White	White	White	Purple
Leaf blade color	Light green	Green	Green	Green	Green with purple at the edge
Leaf sheath color	Green	Green	Green	Green	Green with purple stripes
Auricle color	Colorless	Colorless	Colorless	Colorless	Purple stripes
Leaf surface	Hairless	Hairless	Hairless	Hairless	Hairless
Ligule type	Cleft	Cleft	Cleft	Cleft	Cleft
Flag leaf angle	<45°	>90°	>90°	90°	<45°
Stem color	Green	Green	Golden yellow	Green	Green
Flowering age	61 DAP*	72 DAP*	69 DAP*	63 DAP*	61 DAP*
Panicle type	Semi-compact	Intermediate	Intermediate	Semi-compact	Intermediate

Stigma color	White	White	White	White	Purple
Harvest age	96 DAP*	105 DAP*	102 DAP*	100 P*	96 DAP*
Grain shape	Lean	Round	Round	Lean	Lean
Lemma and *Palea* color	Straw yellow	Straw yellow	Straw yellow with golden yellow stripes	Reddish to light purple	Brownies orange

*Days after planting

Agronomic traits

Table 2. Average plant height of the five local rice varieties at the generative stage (75 days after planting), leaf length, leaf width, numbers of tillers, and number of productive tillers

Rice varieties	plant height (cm)	Leaf length (cm)	Leaf width (cm)	Number of tillers	Number of productive tillers
V1 'Ketan Genjah'	115.67^{a}	24.82^{ab}	1.68^{bc}	67.80^{d}	58.73^{c}
V2 'PIM'	147.80^{b}	40.73^{c}	2.35^{d}	28.53^{a}	26.93^{a}
V3 'Pendok'	180.13^{c}	46.47^{d}	1.79^{c}	50.47^{b}	43.87^{b}
V4 'Padi Merah'	125.40^{a}	27.82^{b}	1.50^{a}	61.27^{c}	57.60^{c}
V5 'Padi Hitam'	124.47^{a}	23.49^{a}	1.64^{b}	61.53^{c}	55.47^{c}

Remarks: Numbers followed by the same letters in the same column show no significant difference based on DMRT test at $P<0.05$

Plant height can directly affect the yield of rice. Taller plants tend to have longer panicles which can lead to more yield. On the other hand, taller plants are prone to lodging, but if the plants are too short, it will lead to insufficient growth and yield [17]. As presented in Table 2, in this investigation, the highest plant height was found in 'Pendok' with a distinct 180.13 cm. Moles et al. [18] reported that plants in tropical areas are statistically taller in the tropics. This could imply that 'Pendok' is an original local rice variety that has not been too tainted by other genes. Whilst the other varieties were ranging from 115.67 to 147.80 cm tall. Numerically speaking, the shortest plant height was observed in 'Ketan Genjah'. Plant height is a central part of an ecological strategy. Plants can genetically adjust their height in response to the environmental condition [18]. The decrease of essential supplies such as water in rice can lead to dwarfism as a survival response [19]. With the challenge of climate changes nowadays, shorter rice plant is commonly preferred, although it does not omit taller plants as potential germplasm sources for the future ahead. Leaf length and width can describe the leaf area index of a plant. The leaf area index is directly related to the canopy photosynthetic rate [20] which affects the yield. Among all the varieties observed in this study, the longest leaf was found in 'Pendok' at 46.47 cm and the widest leaf was found in 'PIM' at 2.35 cm.

Tiller is a panicle-bearing organ in rice. A productive tiller is described as a tiller that can successfully bear a panicle. Thus, the number of tillers is an important criterion in rice as it can directly affect the yield [21]. In this study, the highest number of productive tillers were observed in 'Ketan Genjah', 'Padi Merah', and 'Padi Hitam'.

Table 3. Average of Panicle length, pithy grain per panicle, percentage of pithy grain, percentage of grain loss, the weight of 1000 grain, and yield per clump of the five local rice varieties

Rice varieties	Panicle length (cm)	Pithy grain per panicle (%)	Grain loss (%)	Weight of 1000 grain (g)	Yield per clump (g)
V1 'Ketan Genjah'	23.10^{a}	88^{bc}	22^{b}	23.30^{a}	150.82^{c}

V2 'PIM'	27.04[c]	59[a]	21[b].	22.30[a]	98.87[a]
V3 'Pendok'	24.91[b]	95[d]	5[a]	33.71[b]	151.38[c]
V4 'Padi Merah'	23.40[a]	84[b]	23[b]	25.30[a]	113.05[ab]
V5 'Padi Hitam'	22.66[a]	90[cd]	25[b]	24.03[a]	130.26[bc]

Remarks: Numbers followed by the same letters in the same column show no significant difference based on DMRT test at P<0.05

According to Mongiano et al. (2020), panicle length, number of grains, and grain size are positively correlated with yield. As shown in Table 2, 'PIM' was observed of having the longest panicle with 27.04 cm. However, this is contrary to the yield per clump result in which 'PIM' was the lowest with 98.87 g. This is due to the fact that 'PIM' has the lowest percentage of pithy grain per panicle at 59%, meaning that other 41% of the grains were sterile.

In terms of pithy grain per panicle, 'Pendok' was found to be the highest with 95%, and also had the lowest percentage of grain loss with a distinct 5% compared to the other four varieties. 'Pendok' also contributes the biggest grain size which was represented by having the highest weight of 1000 grains of 33.71 g. These results were again reflected in the yield per clump. 'Pendok' has the highest yield per clump of 151.38 g, together with 'Ketan Genjah' at 150.82 g which has a high number of productive tillers.

5. Conclusion

Our study gave a summary of the morphological and agronomical performance of five local varieties of rice (*Oryza sativa*, L.) grown in a greenhouse setting using polybags with basic planting fertilizer. Several agronomically important traits such as relatively short flowering age and harvest age, and plant height, moderately high 1000-grain weight, and yield per clump were found in several varieties we characterized in this study. Our study landmarks one of the initial steps in plant breeding programs which could provide critical information for selecting and combining parental lines, especially by utilizing local varieties of rice in Indonesia as valuable genetic resources.

References

[1] Purnamaningsih R. 2016. Induksi Kalus dan Optimasi Regenerasi Empat Varietas Padi melalui Kultur In Vitro. Jurnal AgroBiogen, 2(2), 74.
[2] Prasad B. J., Sharavanan P. S., and Sivaraj R. 2019. RETRACTED: Health benefits of black rice – A review. Grain & Oil Science and Technology, 2(4): 109–113.
[3] Agustin A. T., Safitri A., and Fatchiyah F. 2021. Java red rice (Oryza sativa l.) nutritional value and anthocyanin profiles and its potential role as antioxidant and anti-diabetic. Indonesian Journal of Chemistry, 21(4): 968–978.
[4] Anhar A., Sumarmin R., Etika, S. B., Doni F., Fathurrahman F., and Yusoff W. M. W. 2017. Local red rice genotypes with low glycemic index for people with diabetes mellitus. Ecology, Environment, and Conservation, 23(2): 726–733.
[5] Indonesian Center for Rice Research. 2019. Laporan Tahunan 2019. Indonesian Center for Rice Research
[6] Sitaresmi T., Wening R. H., Rakhmi A. T., Yunani N., and Susanto U. 2015. Pemanfaatan Plasma Nutfah Padi Varietas Lokal dalam Perakitan Varietas Unggul. Iptek Tanaman Pangan, 8(1): 22–30.
[7] Abdullah, B; Tjokrowidjojo, S; Sularjo. 2008. Perkembangan dan Prospek Perakitan Padi Tipe Baru di Indonesia. Jurnal Penelitian dan Pengembangan Pertanian.
[8] Suhartini T. 2016. Keragaman Karakter Morfologis Plasma Nutfah Spesies Padi Liar (*Oryza* spp.). Buletin Plasma Nutfah, 16(1): 17.

[9] Myint K. M., Courtois B., Risterucci A. M., Frouin J., Soe K., Thet K. M., Vanavichit A., and Glaszmann J. C. 2012. Specific patterns of genetic diversity among aromatic rice varieties in Myanmar. Rice, 5(1): 1–13.
[10] Yunandra, Syukur M., and Maharijaya D. A. 2017. Seleksi dan Kemajuan Seleksi Karakter Komponen Hasil pada Persilangan Cabai Keriting dan Cabai Besar. Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy), 45(2): 169.
[11] Rahmawati D., Santika P., and Gultom A. 2021. Yield and seed quality evaluation of several rice (Oryza sativa L.) lines with 'Ciherang' as a comparative variety. IOP Conference Series: Earth and Environmental Science, 672(1), 012012
[12] Liu Q., Han R., Wu K., Zhang J., Ye Y., Wang S., Chen J., Pan Y., Li Q., Xu X., Zhou J., Tao D., Wu Y., and Fu X. 2018. G-protein βγ subunits determine grain size through interaction with MADS-domain transcription factors in rice. Nature Communications, 9(1): 1–12.
[13] Pangeran F. and Rusyanti N. 2018. Characteristics And Quality Of Local Rice In Bulungan District, North Kalimantan. Canrea Journal: Food Technology, Nutrition, and Culinary Journal, 1(2): 107–117.
[14] Song Q., Zhang G., and Zhu X. G. 2013. Optimal crop canopy architecture to maximize canopy photosynthetic CO 2 uptake under elevated CO2-A theoretical study using a mechanistic model of canopy photosynthesis. Functional Plant Biology, 40(2): 109–124.
[15] Rohaeni W. R. and Yuliani D. 2019. Morphological Variability in Leaf of Indonesian Rice Landraces and Its Correlation to Bacterial Leaf Blight Disease Resistance. Jurnal Ilmu Pertanian Indonesia, 24(3): 258–266.
[16] Naveenkumar R., Singh V., Singh P. K., and Anandan A. 2021. Pattern of genetic variation in rice (Oryza sativa l.) population for sheath blight resistance over the seasons. Indian Journal of Genetics and Plant Breeding, 81(1): 132–134.
[17] Hao X., Ma X., Hu P., Zhang Z., Sui G., and Hua Z. 2010. Relationship Between Plant Type and Grain Quality of Japonica Hybrid Rice in Northern China. Rice Science, 17(1): 43–50.
[18] Moles A. T., Warton D. I., Warman L., Swenson N. G., Laffan S. W., Zanne A. E., Pitman A., Hemmings F. A., and Leishman M. R. 2009. Global patterns in plant height. Journal of Ecology, 97(5): 923–932.
[19] Ahmadikhah A., and Marufinia A. 2016. Effect of reduced plant height on drought tolerance in rice. 3 Biotech, 6(2): 1–9.
[20] Vaesen K., Gilliams S., Nackaerts K., and Coppin P. 2001. Ground-measured spectral signatures as indicators of ground cover and leaf area index: the case of paddy rice. Field Crops Research, 69(1): 13–25.
[21] Mongiano G., Titone P., Pagnoncelli S., Sacco D., Tamborini L., Pilu R., and Bregaglio S. 2020. Phenotypic variability in Italian rice germplasm. *European Journal of Agronomy*, 120.
[22] Nurhasanah, Sadaruddin, and Sunaryo W. 2017. Yield-related traits characterization of local upland rice cultivars originated from east and North Kalimantan, Indonesia. Biodiversitas, 18(3): 1165–1172.