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Agronomic Variations of Functional Upland Red and Black Rice Promising Lines in Medium Altitude Dryland Areas of Central Lombok, Indonesia

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ABSTRACT

The objective of this study was to determine the variation in agronomic characters of functional upland red rice and black rice promising lines grown in the dryland area of medium altitude in Central Lombok, Indonesia. The field experiment was carried out from May to August 2022, which was arranged according to Randomized Completely Block Design. The genetic materials tested were 15 genotypes consisting of six lines of F5 red rice, five lines of black rice, three parental genotypes, and one comparison variety of upland red rice. Each genotype was replicated in three blocks. The agronomic characters observed included plant height, flowering date, harvesting date, number of productive tillers (or panicles), panicle length, number of filled and unfilled grains per panicle, weight of 1000 grains, grain weight per clump, and grain yield potential. The results showed that there was a fairly high agronomic variation among those 15 functional upland rice genotypes especially on plant height, flowering date, harvesting date, panicle number per clump, filled grain number per panicle, weight of 1000 grains, weight of grains per clump, and grain yield potential. These findings indicate that there are some desirable traits of those agronomic characters that could be used for breeding new superior functional upland red and black rice varieties adaptable on the dryland of medium altitude in Central Lombok, Indonesia, or elsewhere.

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KEYWORDS: agronomic variation; functional rice; red rice; black rice; dryland; medium altitude

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1. INTRODUCTION

One of the most important staple foods in Indonesia is rice produced from paddy rice plants. Rice germplasm in Indonesia varies in shapes, sizes, colors, flavors, and aromas [1], [2]. As reported by Mau et al. [3] that more than 40 accessions germplasms of upland rice in East Nusa Tenggara (NTT) possessed a high genetic diversity. The same as reported by Aryana [4] that more than 34 local varieties of upland rice in West Nusa Tenggara (NTB), in such six cultivars of Lombok upland rice were characterized to have morphological diversity expected to be used as genetic material in rice plant breeding [2]. Based on the color of the rice grain skin, there are white rice, brown rice, red rice, and black rice [5]. Red rice and black rice are functional rice because the rice content has one or more compounds that are beneficial to human health such as antioxidants, beta carotene and anthocyanin which are quite high [6]. Abdullah [7] reported that red rice contains protein (9.04%), fat (1.59%), amilose (21.42%), amylopectin (45.65%), starch (67.07%), beta-carotene (158.29 mg/100 g), anthocyanins (2.88 ppm), while black rice contains protein (5.51%), fat (1.85%), amilose (22.97%), amylopectin (51.54%), starch (74.52%), beta-carotene (804.16 mg/100 g), and anthocyanins (393.93 ppm).

Both red rice and black rice have a good taste and aroma with a specific and unique appearance. The red and black rice have better properties than white rice. The red rice and black rice are efficacious in increasing the body's resistance to diseases, repairing liver cell damage ("hepatitis" and "chirosis"), preventing kidney function disorders, preventing cancer/tumors, slowing aging, as antioxidants, clearing cholesterol in the blood, and preventing anemia. In addition, black rice functions as a natural dye for the food industry in the form of cakes, porridge, biscuits, ice cream and fermented beverages [6]. In Bali, the red and black rice are used as a means of many kinds of Hindu's ceremonies in the form of "pecaruan", "pesegahan" and "krikkramas" [8], [9], [10].

The existence of red and black rice in Indonesia is increasingly scarce due to the cultivation of new high-yielding varieties of rice dominated by white rice. The high-yielding varieties released by the Ministry of Agriculture to date amount to more than 233 varieties consisting of 144 high-yielding varieties of inbred rice (Inpari), 35 varieties of hibred rice (Hipa), 30 high-yielding varieties of upland rice (Inpago), and 24 varieties of fresh water swampy rice (Inpara), most of which are produced by the Agricultural Research and Development Agency [11]. Many varieties were also released by several universities such as IPB with IPB 3S and IPB 4S varieties (released in 2012), Unsoed with Inpago Unsoed-1 (released in 2011) and Unram with Inpago Unram-1 (released in 2011) through the National Rice Consortium activities initiated by the Sukamandi Rice Research Center. Most of the high-yielding varieties of rice released above are white rice. The Inpago Unram-I variety is a high-yielding variety of red upland rice. Until now, superior varieties of ideal type red upland rice and black upland rice adaptive in the dryland of medium highland have not been released. It is therefore very important to know the existence of potential sources of parentals who have extensive morphological and agronomic variations for the formation of the high-yielding upland functional rice variety.

The dryland of the medium plain in Central Lombok district is quite large and has not been optimally utilized, as well as having considerable potential for the development of upland rice to increase land productivity. Batukliang Subdistrict is a medium plain region in Central Lombok characterized by an inclined land slope of 15-40% to a very sloping >40%, at most around 11,000 ha and has the highest annual rainfall (163 mm/year) [12].

New genetic resources having the potential for the breeding of superior varieties of the ideal and new types functional upland rice with high grain yield potential and early maturity to be developed in the dryland of medium plain are very necessary since there are many rice germplasms for these properties have not been identified. Aryana and Sudharmawan [13] reported that an upland red rice expected line F2BC4P19-36 which has a high anthocyanin content has been produced resulted from the 4 (four) times back cross of the expected lines of drought-tolerant red rice and the local cultivar of Kala Isi Tolo red rice, which has a high anthocyanin content and early maturity of 107 days, and high tiller number per clump, but still has a relatively low grain yield potential of 5.8 t/ha. This line was then crossed with IPB 3S (which has a potential yield of 11.2 t/ha, early matured 112 days, texture of fluffy rice with white rice color, small number of tillers) and Fatmawati (has a potential yield of 9 t/ha, early matured 115 days with a texture of fluffed rice, white rice color, small number of tillers) through single and repeated cross-selection, which was then followed by pedigree selection up to F5 and produced new superior red rice lines and ideal types [10],[14]. Similarly, from the result of a single cross between local paddy rice of black rice "Baas Selem" (which has fluffy, fragrant aroma, very high anthocyanin content, but low yield potential ranging from 2 - 4 t/ha) and the upland rice variety of Situ Patenggang (which is drought tolerant, high-yielding > 6 t/ha, white rice national cultivar), which is then subjected to bulk selection up to F10 and continued with pedigree selection up to F4 and produced a new type of upland black rice promising line, high-yielding and early-maturity [10].

II. MATERIALS AND METHODS

The study was carried out on the dryland of medium plain at Tampak Siring village, Batukliang district, Central Lombok Regency, West Nusa Tenggara province (Indonesia) with an altitude of 373 m above sea level, from June to August 2022. The experiment was laid out in a Randomized Complete Block Design with 15 functional upland rice genotypes as the treatments, each of which was grown in three blocks (replications). The fifteen functional upland rice genotypes (presented in Table 1) consisted of six red rice lines (G1 - G6), five black rice lines (G7 - G11), three parental genotypes namely the red rice promising line (RRPL) "F2BC4P19-36" (G12), "Baas Selem" local cultivar (G13), "Situ Patenggang" cultivar (G14), and a comparison cultivar "Inpago Unram-1" (G15). Each treatment was sown on an experimental plot measuring 2 x 4 m, with a planting distance of 25 x 25 cm, planted with one pre-germinated seed per planting hole. Fertilization was done using Phonska (NPK) fertilizer as basal fertilization at a dose of 300 kg/ha, and Urea fertilizer (45% N) at a dose of 200 kg/ha applied at 50 days after seeding (DAS).

The agronomic traits observed were plant height, flowering date, harvesting date, number of productive tillers per clump, number of non-productive tillers per clump, panicle length, number of filled grain per panicle, number of unfilled grain per panicle, weight of 1000 grains, and grain weight per clump. Grain yield potential (t/ha) with a moisture content of 14% was obtained from the yield of 1 m^2 and then converted to t/ha. Measurements are done according to the variables observed, both before and after harvest. Sample plants were taken as many as 10 plants per experimental unit which were carried out using systemic random sampling, namely by taking sample plants randomly in each experimental unit. Data were analyzed with analysis of variance (ANOVA) and further tested for mean differences with DMRT (Duncan Multiple Range Test) at 5% significance level using the SAS 16 for Windows program.

Table 1. Fifteen genotypes of functional upland red rice and black rice tested in this study

Treatment Codes	Genotypes	Type of rice
G1	F5 IPB3S/F2BC4P19-63//Fat/F2BC4P19-63-PD3/7	Red rice line (RRL)
G2	F5 IPB3S/F2BC4P19-63//Fat/F2BC4P19-63-PD3/15	Red rice line (RRL)
G3	F5 IPB3S/F2BC4P19-63//Fat/F2BC4P19-63-PD3/20	Red rice line (RRL)
G4	F5 IPB3S/F2BC4P19-63//Fat/F2BC4P19-63-PD3/13	Red rice line (RRL)
G5	F5 IPB3S/F2BC4P19-63//Fat/F2BC4P19-63-PD3/71	Red rice line (RRL)
G6	F5 IPB3S/F2BC4P19-63//Fat/F2BC4P19-63-PD3/83	Red rice line (RRL)
G7	F91/1/6/I/P3	Black rice line (BRL)
G8	F92/1/1/4/I/P3	Black rice line (BRL)
G9	F92/1/2/1//I/P3	Black rice line (BRL)
G10	F91/1/6//P3	Black rice line (BRL)
G11	F91/1/1/6/P3	Black rice line (BRL)
G12	F2BC4P19-36	Red rice promising line (RRPL)
G13	Baas Selem	Black rice local cultivar
G14	Situ Patenggang	Upland white rice cultivar
G15	Inpago Unram-1	Upland red rice cultivar

Notes: The 12 lines (G1-G12) were developed by Aryana et al. (2016); G13, G14 and G15 are national rice cultivars

III. RESULTS

Based on the results of ANOVA (analysis of variance) of the agronomic variables, it appears that the agronomic traits are significantly different (*p-values* <0.05) among the genotypes tested, except for panicle length (Table 2) and unfilled grain number per panicle (Table 3), which are non-significantly different (*p-values* ≥ 0.05) among those genotypes. Based on the mean comparison test on plant height, the tallest genotypes were G2 (122.19 cm) and Inpago Unram-1 (G15) (121.74 cm height) and the shortest one was the black rice line G9 (95.07 cm).

Table 2. Average plant height, flowering date, harvesting date, panicle number/clump and panicle length of the functional upland red and black rice lines grown in a medium altitude dryland area of Central Lombok, Indonesia

Genotypes	Plant height (cm)	Flowering date (DAS)	Harvesting date (DAS)	Panicle number/clump	Panicle length (cm)
G1 (RRL)	101.37 cd	83.33 ab	114.67 a	12.96 abcd	21.72
G2 (RRL)	122.19 a	80.33 b	112.00 bcd	13.04 abcd	24.84
G3 (RRL)	104.63 bcd	84.00 ab	111.67 cd	15.96 ab	22.74
G4 (RRL)	111.89 abc	84.00 ab	111.67 cd	12.11 ab	22.40
G5 (RRL)	106.30 bcd	80.00 b	113.67 abc	17.15 ab	23.01
G6 (RRL)	113.67 abc	84.67 ab	111.00 de	17.59 ab	23.63
G7 (BRL)	104.85 bcd	85.67 ab	114.67 a	9.81 d	20.47
G8 (BRL)	108.85 bcd	89.67 a	115.33 a	9.93 cd	20.75
G9 (BRL)	95.07 d	89.33 a	111.67 cd	15.85 abc	21.08
G10 (BRL)	112.96 abc	89.33 a	114.00 ab	12.93 abcd	21.62
G11 (BRL)	108.96 bcd	86.00 ab	109.00 ef	17.85 ab	21.38
G12 (RRPL)	115.67 ab	85.33 ab	107.33 f	16.41 ab	22.14
G13 (Baas Selem)	103.96 bcd	87.00 ab	110.00 de	14.63 abcd	22.28
G14 (Situ Patenggang)	107.48 bc	84.33 ab	111.00 de	18.85 a	22.94
G15 (Inpago Unram-1)	121.74 a	79.33 b	107.33 f	18.89 a	23.94
ANOVA	Significant	Significant	Significant	Significant	Non-significant

Note: Mean values in the same column followed by the same letters are not significantly different between genotypes

Table 2 also shows that flowering dates (days to flowering) of the 15 functional upland rice genotypes range from 79.33 – 89.67 days after sowing (DAS). The earliest flowering genotype was the upland red rice variety "Inpago Unram-1" (79.33 DAS) and the latest one was the black rice line F92/1/1/4/I/P3 (G8) (89.67 DAS). For the harvesting date, the results indicated that the earliest maturity genotype was the Inpago Unram-1 (G15) (107.33 DAS) and the RRPL F2BC4P19-36 (G12) (107.33 HST) while the latest one was the RRL F5 IPB3S/F2BC4P19-63//Fat/F2BC4P19-63-PD3/7 (G1), black rice lines F91/1/6/I/P3 (G7), and F92/1/1/4/I/P3 (G8) (114.67, 114.67, and 115.33 HST respectively). In addition to the latest maturity, G7 and G8 also produced the lowest number of panicles per clump (9.81 and 9.93 panicles/clump, respectively, while the genotypes producing the highest number of panicles were Inpago Unram-I and Situ Patenggang (18.89 and 18.85 panicles/clump), whereas panicle length was not significantly different among the genotypes tested.

Based the grain characters of the 15 functional upland rice genotypes grown in the medium highland of Central Lombok NTB (Table 3), the average number of filled grains per panicle was in the range of 88.22 – 137.83 grains/panicle. The highest number of grains per panicle was in Inpago Unram-1 (137.83 grains) and the lowest one was in the black rice line F92/1/2/1//I/P3 (G9) (88.22 grains/panicle). The number of filled grain among the red rice lines did not vary as well as among the black rice lines. It can also be seen that there was no difference in the number of filled grains among the red rice lines and the black rice lines.

Table 3 also shows that the weight of 1000 grains ranges from 27.4 g to 31.6 g, with the highest weights was in the red rice line F5 IPB3S/F2BC4P19-63//Fat/F2BC4P19-63-PD3/15 (G2), i.e. 31.6 g and the lowest one was in the black rice line F92/1/1/4/I/P3 (G8), i.e. 27.4 g. However, the genotype producing the highest 1000 grain weight did not produce the highest grain yield per clump, in which the highest grain yield per clump was shown by the red rice line F5 IPB3S/F2BC4P19-63//Fat/F2BC4P19-63-PD3/83 (G6) (47.93 g), while the lowest grain yield was in the red rice line F5 IPB3S/F2BC4P19-63//Fat/F2BC4P19-63-PD3/7 (G1) (25.81 g).

Although the mean value of grain yield was in G6, this genotype showed non-significant mean value of grain yield per clump with its parent (G12) (35.70 g) and with the comparison variety Inpago Unram-1 (40.41 g). The grain yield potential per hectare of the genotypes tested highly varied (Table 3) with the average yields range from 5.59 t/ha to 7.05 t/ha (Table 3). The highest grain yield potential was seen in the comparison variety "Inpago Unram-1" (G15) (7.05 t/ha) and the lowest was in the black rice line G9 (5.59 t/ha). The grain yield potential between the red rice lines (G1-G6) and their parents RRPL (G12) did not significantly different, as well as between the black rice lines (G7-G11) and their parents (Baas Selem and Situ Patenggang), but differed with the comparison variety "Inpago Unram-1".

Table 3. The average numbers of filled grains, unfilled grains, weight of 1000 grains, weight of grains per clump, and the grain yield potential per hectare of the functional upland red and black rice lines grown in a medium altitude dryland area of Central Lombok, Indonesia

Genotypes	Filled grain number/panicle	Unfilled grain number/panicle	Weight of 1000 grains (g)	Grain yield per clump (g)	Potential yield (t/ha)
G1 (RRL)	109.39 abc	18.91	29.0 abc	25.81 c	5.86 bc
G2 (RRL)	114.04 abc	21.39	31.6 a	40.63 ab	5.40 c
G3 (RRL)	111.13 abc	20.74	29.1 abc	34.15 abc	5.86 bc
G4 (RRL)	124.24 abc	21.59	28.7 abc	35.37 abc	5.90 bc
G5 (RRL)	108.91 abc	20.22	29.9 abc	37.37 abc	5.64 c
G6 (RRL)	122.91 abc	22.67	29.8 abc	47.93 a	5.87 bc
G7 (BRL)	119.17 abc	15.30	28.0 bc	31.15 bc	5.62 c
G8 (BRL)	123.35 abc	18.20	27.4 c	28.15 bc	5.62 c
G9 (BRL)	88.22 c	14.17	29.6 abc	34.67 abc	5.59 c
G10 (BRL)	122.54 abc	16.26	27.7 bc	39.04 abc	5.74 bc
G11 (BRL)	109.17 bc	19.56	29.5 abc	40.78 ab	5.76 bc
G12 (RRPL)	123.04 abc	20.54	28.8 abc	35.70 abc	6.35 b
G13 (Baas Selam)	100.22 bc	18.07	28.4 bc	32.85 bc	5.43 c
G14 (Situ Patenggang)	121.70 abc	17.31	28.4 bc	40.59 ab	6.03 bc
G15 (Inpago Unram-1)	137.83 a	14.20	30.9 ab	40.41 ab	7.05 a
ANOVA	Significant	Non-significant	Significant	Significant	Significant

Note: The numbers followed by the same letters in the same column did not differ significantly on a 5% DMRT test.

IV. DISCUSSION

Plant height is a measure often observed as an indicator of growth and as a parameter used to determine crop production [15]. IRRI [16] groups plant height into categories: short (<110 cm), moderate (110-130 cm), and tall (>130 cm). Based on these categories, all genotypes tested as presented in Table 3 were relatively short paddy rice except for the red rice lines F5 IPB3S/ F2BC4P19-63//Fat/F2BC4P19-63-PD3/15, F5 IPB3S/ F2BC4P19-63//Fat/F2BC4P19-63-PD3/ 13, and F5 IPB3S/F2BC4P19-63//Fat/F2BC4P19-63-PD3/83 are classified as medium height paddy rice, similar to the black rice line F91/1/6//P3; GH red rice and Inpago Unram-1. Those genotypes were still shorter compared to two Lombok local upland rice cultivars, i.e. Pare Beaq Ganggas 148 cm dan Pare Beaq Sapit 146.7 cm, as reported by Hartina et al. [2]. The taller plants tend to lie down easily due to environmental factors such as strong winds impact. As Zen [17] reported that shorter plants will avoid lying down due to the wind, so that such plants are easy to care for.

Flowering date ranges from 79.33 – 89.67 days after sowing (Table 2). The earliest flowering genotype was the Inpago Unram-1 variety (79.33 DAS) and the latest one was black rice line F92/1/1/4/I/P3 (G8) (89.67 DAS). Based on the flowering date classifications, all genotypes tested were in the category of early flowering (71-90 days) similar to those reported by Suryanugraha et al. [18]. Chandrasari et al. [19] reported that rice plants flowering earlier will have an earlier generative phase. The earlier the rice plants start anthesis, the earlier the harvesting date will be. Aryana et al. [20] also reported that knowing the flowering date is important in order to determine the time for sowing the seeds to synchronize flowering and to get the same harvesting date.

The panicle length ranges 20.47 – 23.94 cm and showed no differences among the genotypes tested (Table 2). The length of the panicle is a selection criterion for rice breeding because it affects grain yield. Plants that have long panicles will provide more grain so that the yield obtained becomes higher [21]. Panicle lengths are classified into 3 (three) groups: short panicles (< 20 cm), medium panicles (20-30 cm) and long panicles (>30 cm) [22]. Based on this classification, all genotypes tested are in medium category (20-30 cm). To improve panicle length, Lombok local upland rice Beaq Ganggas (39.2 cm) might be used as a gene source for panicle length [2].

The number of productive tillers or panicles per clump ranges 9.81–18.89 tillers (Table 2). The lowest number of panicles per clump was found in the black rice line F91/1/6/I/P3 (G7) (9.81 tillers) and the highest ones were in Inpago Unram-I and Situ Patenggang (18.89 and 18.85). According Endrizal and Bobihoe [23], productive tillers per clump are a determinant of the number of panicles, thus the tillers have a direct effect on the high and low grain yield. Hatta [24] reported that the number of the productive tillers is related to yield; a small number of tillers indicates low grain yield. Meanwhile, there was no difference of the number of non-productive tillers among genotypes (data are not shown). As reported by Aryana et al. [10], tillers formed in the late stages of the vegetative phase tend to be incapable of producing panicles. The non-productive tillers are competitors of productive tillers in utilizing sunlight energy and nutrients. In addition, more non-productive tillers will lead to an increasingly humid microenvironment, providing opportunities for the development of pests and diseases.

As indicated in Table 3, all red and black rice lines except for two black rice lines (G9 and G11) had no different in the number of filled grains per panicle with Inpago Unram-1. The number of filled grains per panicle is an important trait in breeding high yielding rice. Zhengjin et al. [25] developed an ideal type of rice with filled grain number more than 200 grains per panicle. The number of filled grains per panicle correlates with grain yield but is also influenced by unfilled grain number. Yield of rice is determined by the yield components such as the number of filled grains per panicle and the weight of 1000 grains. Each genotype has a different grain yield capability depending on its genetic traits. This can be seen by the difference in the number of filled grains between the genotypes tested and the comparison variety (G15).

The weight of 1000 grains is one of the components that affect the yield. According to Ma et al. [26] for an ideal type of rice it takes a weight of 1000 seeds between 28 - 30 g. Some local Indonesian rice varieties were also reported to have even less than 15 g [1]. The heavier the 1000 grain weight, the higher the yield could be obtained [27]. However, Maintang et al. [28] reported that the weight of 1000 grains is not always followed by high yields. As shown in Table 3 that the red rice line F5 IPB3S/F2BC4P19-63//Fat/ F2BC4P19-63-PD3/15 (G2) has the highest weight of 1000 grains (31.6 g) but its grain yield potential was lower (5.40 t/ha). Compared to Inpago Unram-1 (G15), its 1000 grain weight was not the highest (30.9 g), but its grain yield potential was the highest 7.05 t/ha.

The weight of grains per clump of rice plants is generally strongly affected by the number of filled grains per panicle, the number and length of panicles, and the weight of 1000 grains [29]. Nurhidayah et al. [30] also added that the number of filled grains determines the weight of grains per clump of a rice plant. This can be seen in the G15, which has a relatively large amount of filled grain compared to the parent “Baas Salem” (G13), which has a small amount of filled grain (Table 3). Therefore, weight of grains per clump of the G15 genotype was higher and its grain yield potential was also higher (7.05 t/ha).

Grain yield potential describes the grain yield of plant obtained in one area of land in one planting cycle. According to Aryana et al. [31], high grain yield potential in paddy rice could be influenced by the yield components such as the number of productive tillers per clump, the length of the panicle, the number of filled grain per panicle, and the weight of grain per clump. G15 (Inpago Unram-1) as a comparison variety was a genotype that has a higher grain yield potential compared to all lines tested and also the red and black rice parental genotypes.

V. CONCLUSION

There was a fairly high variation in agronomic traits of the 15 functional upland rice genotypes, especially on plant height, flowering date, harvesting date, number of productive tillers, number of filled grains, weight of 1000 grains, weight of grains per clump, and grain yield potential. These findings indicate that there are some desirable traits of those agronomic characters that could be used for breeding new superior functional upland red and black rice varieties adaptable on the dryland of the medium altitude in the Central Lombok of the West Nusa Tenggara Provinve, Indonesia.

VI. ACKNOWLEDGEMENT

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VII. DISCLOSURE

We do not have any conflicts of interest in this work.

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