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Potential of Upland Rice Promising Lines in Acid Dry Land at Two Different Seasons

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ABSTRACT

Superior upland rice varieties can be obtained through the plant breeding process. Upland rice lines that are carried out from crossing have different potentials. The research aims to determine upland rice promising lines with high yields in acid-dry land. The study is conducted on Ultisol soil. The first season is in 2019 for F_6 lines, and the second is in 2021 for F_7 lines. The experimental methods use factorial Randomized Block Design (RBD). The treatment at the preliminary yield test use 5 lines 4 varieties, and 1 landrace. The advanced yield test uses 5 F_7 lines (selected from F_6 lines) and 5 types. Analysis data use ANOVA and LSI test. The result shows that lines GH_8 and GH_{10} have the highest yields on acid-dry soils during two planting seasons. The GH_{10} line has a 7.20-9.53 kg/plot yield, and the GH_8 line has a 5.22-6.26 kg/plot. The highest yield potential was the GH_{10} line of 3.69-4.77 t/ha, more increased than Balok, Banyuasin, Danau Gaung, Inpago 8, and PBM-UBB1 varieties. GH_{10} and GH_8 lines are recommended as candidates for new superior varieties of upland rice that are adaptive to acid-dry soils.

INTRODUCTION

Rice (*Oryza sativa* L.) is a primary food crop in Indonesia. The color of rice is caused by the content of anthocyanin pigment (Rathna Priya, Eliazer Nelson, Ravichandran, & Antony, 2019). Total anthocyanin content is higher than white rice (Agustin, Safitri, & Fatchiyah, 2021). Anthocyanins are phenolic compounds that function as antioxidants (Maulani, Sumardi, & Pancoro, 2019). Brown rice has different phenolic content (Gujral, Sharma, Kumar, & Singh, 2012), and white rice has different nutritions (Handajani, Sulandari, Purwidiani, & Zamroh, 2020). The public prefers red rice because it has higher nutrition, but it needs to be developed.

The capacity of food production requires agricultural land that is proportional to the Indonesian population (Rasyid & Kusumawaty, 2022). The main problem of agricultural land in Indonesia is caused by land conversion (Rochadi, Sadiyatunnimah & Salim, 2022). The arable land is getting narrower because used for industry, houses, and others (Munir, Afiyah, & Munir, 2023). Agricultural transformation is currently being pursued in sub-optimal land areas to increase agricultural production (Riswani, Yunita, & Thirtawati, 2022). Indonesian farmers have recently started to cultivate ultisol-type soil. Ultisol soil is impoverished in nutrients (Suryani, Idris, Nurmansyah, & Nasir, 2022). Soil types in the Bangka Belitung Archipelago Province are classified as Ultisol. Rice production in this province has not met the needs of its population, so it is necessary to increase rice production.

Ultisol-tolerant upland rice varieties can increase rice production in acid soil types. Ultisol soil contains 82.16% clay, pH 5.19, Org-C 18.8 g/kg, and Al-exch 1.92 me/100 g (Yulnafatmawita & Adrinal, 2014). It is essential to develop rice plants that are adaptive to acid-dry land. Due to drought stress, genotypes that cannot adapt to dry acid soil will inhibit vegetative growth and yield production (Tirtana, Purwoko, Dewi, & Trikoesoemaningtyas, 2021). One rice variety that adapts to acid-dry land is Inpago 8 (Nazirah, Purba, Hanum, & Rauf, 2016). The genotypes that adapted to Ultisol Bangka were PBM UBB 1, Danau Gaung and 21B-57-21-21-23 (Mustikarini, Prayoga, Santi, &

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Wardani, 2022). PBM UBB1 is a brown rice variety. Danau Gaung dan 21B-57-21-21-23 is white rice.

A superior genotype can be obtained through the hybridization process. Hybridization of landrace Bangka rice with national varieties has been done to get lodging resistance lines. In further research, GH_3 and GH_4 from the F_6 lines can be used as candidates for new superior varieties (Mustikarini, Prayoga, Santi, & Hairul, 2021). Rice plant lines that have been produced need to be tested on acid soils. The results of this study are expected to obtain lines that can adapt to Bangka ultisols. It is hoped that the test results for the two growing seasons will yield data on the average yield of the expected lines on ultisols. The research aims to determine upland rice promising lines that have high yields in acid-dry land.

MATERIALS AND METHODS

The research was conducted in two experimental seasons in December 2020 - April 2021, on ultisol land in Universitas Bangka Belitung, Indonesia.

The research method used was the experimental procedure. The research design applied a randomized block design for each season. The treatment in the first season (preliminary yield test) used 10 upland rice lines (GH_1-GH_{10}) (Table 1). The treatment in the second season used 5 lines GH_3, GH4, GH_5, GH_8 and GH_{10} and 5 check varieties (Table 2). Lines GH_4 was the only remaining line of red rice, while the other lines were white rice. In 1 plot (experimental unit), there are 320 plants. The area of 1 plot is 20 m^2.

F_7 generation of rice plants was observed flag leaf length, plant height, number of productive tillers, panicle length, harvest age, number of unfilled grains, 1000 seed weight, yield per plot, and organoleptic tests. Data analysis used Fisher's test (α 5%) and the Least Significant Increase (LSI) test (formula 1).

$$LSI = t_{(0,05;db)} \sqrt{\frac{2MSE}{r}} \quad \ldots\ldots 1)$$

Where: MSE = Mean Square Error; r = replication; $t_{(0,05;db)}$ = t table; α = 5%.

RESULTS AND DISCUSSION

A yield test was carried out identification of lines tolerant to dry acid soils. Plants that tolerate dry, acid soils show high growth and yield. Identification was carried out during two planting seasons. According to Putriani, Yusnaini, Septiana, & Dermiyati (2022), ultisol soil contains 9.14 ppm available-P, 0.98% Organic-C, and 10.78 cmol/kg CEC criteria very low. Ultisol soil has a pH of 3-4, Cation Exchange Capacity (CEC) low and Al-dd high (Muktamar, Lifia, & Adiprasetyo, 2020). Phototoxic aluminum (Al^{3+}) rapidly inhibits root growth, reducing water absorption and nutrients (Rahman et al., 2018). Plants with Al poisoning stunted growth and are abnormal (Herlina & Andarini, 2022).

According to Michel et al. (2017), a preliminary yield test is carried out to determine the potential of superior lines. The initial yield test (season one) showed differences in character between the lines and the comparison varieties. All the lines at this stage had shorter plant heights than all the comparison varieties, except for the Banyuasin variety. The GH_2 line had the shortest plant height of 73.10 cm (Table 1). Rice can be easily identified through phenotype characteristics such as plant height (Rahmawati, Santika, & Fitriyah, 2021; Widyayanti, Hidayatun, Kurniawan, Kristamtini, & Sudarmaji, 2020). The character of plant height < 105 cm is classified as a short plant. The F_6-F_7 generation lines are identified as having short plant height. The character of short plant height was inherited from the two parents of the cross, namely Banyuasin and Inpago 8. According to Huang et al. (2018), plants with short heights allocate more photosynthate to seeds. According to Rahmawati, Santika, & Fitriyah (2021), reducing plant height is the main target to produce lodging resistance in rice.

Two lines had longer flag leaf lengths than the Banyuasin variety, namely GH_1 and GH_3 (Table 1). The number of productive tillers in rice plants affects the number of panicles produced. Early harvest age is thought to result from Inpago 8 and Balok offspring. Mustikarini, Prayoga, Santi, & Hairul (2021) stated that the Hd gene controlled flowering and harvesting age. Weng et al. (2014) indicated that the flowering time gene Ghd7 regulates plant architecture, and genetic and environmental factors influence this regulation. Endo-Higashi & Izawa (2011) stated two essential flowering time genes in rice plants, *Hd1,* and *Ehd1*, also control panicle development. Early harvest age is the desired harvest age in the plant breeding process.

Table 1. Results of LSI test of 17 rice genotypes of preliminary yield test results in generation F_6.

Genotypes	Plant height (cm)	Flag leaf length (cm)	Productive tiller number (tiller)	Flowering age (DAP)	Panicle length (cm)	Harvest age (DAP)	Yield per plot (kg)	Total grain (seeds)	Weight of 1000 seeds (g)
GH_1 (fxd)	86.25 acefg	30.39 b	11.75	79.7 bf	20.52 b	111.00 bf	3.82 f	878.00	25.32 abdef
GH_2 (axb)	73.10 acdefg	22.32	18.10 abcfg	63.4 abcdefgh	15.51	100.50 abcefh	3.48	1118.35 bf	25.39 abdef
GH_3 (fxd)	82.15 acdefg	32.04 bdh	15.90 acf	71.0 abcdefgh	19.30 b	104.00 bfh	4.93 bf	1732.05 bcdf	25.50 abdef
GH_4 (dxa)	96.60 acefg	29.69 b	13.30 c	77.9 abcfh	20.16 b	110.00 bf	5.55 bdf	1104.50 bf	26.38 abdef
GH_5 (axd)	88.20 acefg	26.28	16.30 acf	73.6 abcdefgh	18.79 b	114.00 bf	5.59 bdf	873.50	27.66 abdef
GH_6 (dxa)	86.80 acefg	25.49	12.25 c	73.3 abcdefgh	20.59 b	110.50 bf	2.84	1045.80 bf	24.11 abdef
GH_7 (axb)	88.85 acefg	26.80	13.65 c	75.5 abdefh	19.92 b	110.00 bf	4.15 bf	1082.90 bf	26.03 abdef
GH_8 (axb)	92.30 acefg	27.33	35.50 abcdefgh	71.8 abcdefgh	19.00 b	102.50 abfh	6.26 bdf	2923.75 abcdefgh	23.28 bdef
GH_9 (axb)	75.70 acdefg	19.56	17.80 abcf	75.8 abdefh	15.57	103.50 bfh	5.11 bf	1073.10 bf	24.77 abdef
GH_{10} (axb)	76.30 acdefg	24.39	47.70 abcdefgh	80.7 bf	16.48	112.50 bf	9.53 bcdfh	2546.15 abcdefgh	20.73 bf
Balok + LSI (a)	141.21	46.28	15.45	78.6	25.80	103.15	9.91	1885.28	24.10
Banyuasin + LSI (b)	56.76	29.23	17.30	84.5	16.80	115.15	3.83	932.38	20.23
Danau Gaung +LSI (c)	114.86	42.41	11.90	75.2	27.43	101.15	6.90	1274.58	29.76
Inpago 8 + LSI (d)	82.56	30.48	20.15	77.1	22.39	98.65	5.51	1421.73	22.44
Inpago 12 + LSI (e)	103.66	37.77	18.55	77.8	23.57	102.15	13.23	2417.53	23.13
PBM UBB-1 + LSI (f)	151.41	40.64	14.60	86.9	23.61	122.15	3.63	968.83	18.79
Rindang 1 + LSI (g)	103.56	37.21	18.00	74.6	25.83	97.65	11.53	2116.83	28.48
$\bar{x}g$+LSI (h)	**72.49**	**30.66**	**26.33**	**78.1**	**20.61**	**104.50**	**8.06**	**1918.39**	**27.89**
LSI	**12.14**	**4.23**	**6.10**	**3.9**	**2.03**	**3.35**	**2.93**	**480.58**	**2.98**

Remarks: $\bar{x}g$ = Average offspring genotype lines; The letter behind the number indicates that the test line is better than (a) Balok, (b) Banyuasin, (c) Danau Gaung, (d) Inpago 8, (e) Inpago 12, (f) Rindang 1, and (g) the average genotype of the lineage; The letters in brackets that follow the test line code are the parent of the cross; The test line was better than the comparison on the characters of flag leaf length, number of productive tillers, panicle length, production per plot, total grain count, and 1000 grain weight if the test line check value + LSI, while on the character of plant height, harvest age, and loss if the test line check value – LSI (α = 5%).

Table 2. Results of LSI test of 9 rice genotypes of preliminary yield test results in generation F_6 and F_7 (second seasons).

Genotypes	Plant height (cm)	Flag leaf length (cm)	Productive tiller number (tiller)	Panicle length (cm)	Harvest age (DAP)	Total grain (seeds)	Yield per plot (kg)	Weight of 1000 seeds (g)
GH_3	79.12 abcde	31.83 b	23.63 ac	19.89	114.1	1338.47	4.31	28.85
GH_4	93.74 acd	26.91	17.50	20.48	111.25	1012.29	4.05	34.39
GH_5	95.95 acd	24.61	31.38 abcde	21.13	107.5 abe	1942.46 ab	5.22	29.41
GH_8	71.32 abcde	22.39	42.00 abcde	18.10	113.05	1737.88 b	7.20	23.51
GH_{10}	83.67 abcde	25.85	21.73 a	20.55	114	808.71	4.69	27.53
Danau Gaung + LSI (a)	113.44	43.40	19.90	30.48	109.92	1895.07	14.02	84.51
Inpago 8 + LSI (b)	88.27	30.88	23.78	25.57	107.95	1659.52	8.01	63.83
Inpago 12 + LSI (c)	98.62	36.56	23.55	25.85	105.17	2550.90	13.23	83.83
Rindang + LSI (d)	103.67	38.46	25.15	27.68	105.67	2111.04	16.59	63.08
$\bar{x}g$+LSI (e)	**83.83**	**34.02**	**29.93**	**24.88**	**107.72**	**1963.11**	**10.63**	**57.77**
LSI	**14.66**	**5.06**	**8.15**	**2.83**	**3.83**	**522.34**	**3.67**	**16.20**

Remarks: $\bar{x}g$ = Average offspring genotype lines; The letter behind the number indicates that the test line is better than (a) Danau Gaung, (b) Inpago 12, (c) Inpago 8, (d) Rindang 1, and (e) the average genotype of the lineage; The letters in brackets that follow the test line code are the parent of the cross; The test line was better than the comparison on the characters of flag leaf length, number of productive tillers, panicle length, production per plot, total grain count, and 1000 grain weight if the test line check value + LSI, while on the character of plant height, harvest age, and loss if the test line check value – LSI (α = 5%).

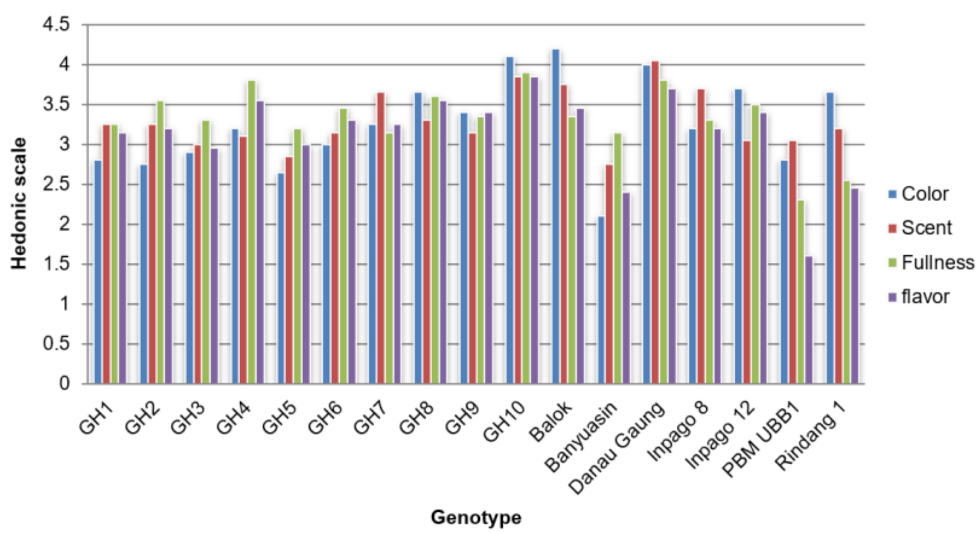

Fig. 1. Panelist's Level of Preference for Color, Aroma, Fluffiness and Taste of Rice

The test line with the longest panicle of 20.6 cm was GH_6, while the shortest, 15.5 cm, was GH_2 (Tabel 1). The longer the panicle, the more grain will be produced. Lines with better characteristics than the comparison varieties can be used as superior lines. The GH_4 line has a plant height of 71.32 cm. This line (GH_4) is classified as having a short plant height (Table 2). All rice plant lines tested had lower plant heights than the check variety. The GH_2 line has the highest plant height of 93.74 cm.

Early harvest age is the desired harvest age in the plant breeding process. The speedy age of rice harvest also does not necessarily increase productivity. The character of the total grain amount is known based on the total number of grains in one plant clump, including empty grain. The total grain number of test lines ranged from 873.5-2923.75, with the highest total grain number of GH_8 (Table 1). A high amount of grain will also be followed by a high crop production. The weight of 1000 seeds of the lines tested showed a higher value than the parents, namely 23.3-27.7 g. The line with the lowest 1000 seed weight was GH_{10}, with an average weight of 20.7 g. The magnitude of the importance of 1000 seeds is not necessarily accompanied by high production.

Mardiah, Septianingrum, Handoko, & Kusbiantoro (2017), stated that the colors consumers like are bright, while consumers do not like dull colors. The rice color of line GH_{10} is preferred because it is red compared to other lines (Fig. 1). A pair of genes belonging to each test line is a combination of two parental alleles. The dominant allele will be expressed, while the recessive allele that is not expressed will still be inherited in the gametes formed in the offspring. Following the dominant trait, one of the parents will produce a white epidermis, while the recessive trait will produce less red epidermis. The Rc gene sequence controls the red color in rice. The OSB1 gene sequence controls black rice, while white rice is controlled by the *DFR* gene (Lim & Ha, 2013).

The GH_{10} line produced grain weighing 9.53 kg/plot, and the GH_8 line produced 6.26 kg/plot grain. The GH_{10} is the line that has the highest yield. The high yield of the GH_{10} lines was supported by the character of yield per plot, productive tillers number, plant height, and harvest age. Mustikarini, Prayoga, Santi, & Hairul (2021) added long panicles have a more significant burden so that rice stalks become curved and prone to fall. It makes long panicles not necessarily able to increase production. The GH_{10} lines have the highest yield in two growing seasons. The second highest yield was GH_8 lines. The GH_{10} line is classified as brown rice.

CONCLUSION AND SUGGESTION

Lines GH_8 and GH_{10} had the highest acid-dry soil yield during two planting seasons. The GH_{10} line had a 7.20-9.53 kg/plot yield, and the GH8 line had a 5.22-6.26 kg/plot. The highest yield potential was the GH_{10} line of 3.69-4.77 t/ha, more increased than Balok, Banyuasin, Danau Gaung, Inpago 8, and PBM-UBB1 varieties. GH_{10} and GH_8 lines are recommended as candidates for superior varieties of upland rice that are adaptive to acid-dry soils.

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