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PRELIMINARY YIELD ASSESSMENT OF THE RICE (*ORYZA SATIVA* L.) F7 PROMISING LINES AT A LOW ALTITUDE

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SUMMARY

In Indonesia, rice production continues to decline due to various problems. As an effort to meet food needs, the utilization of dry land becomes necessary. However, rainfed rice always has low yields. The study, carried out to evaluate potential lines, has succeeded. This research, conducted in the Jenggolo Village, Kepanjen District, Malang Regency, Indonesia, ran from January to June 2024. The breeding materials consisted of six F7 genotypes and three check varieties, namely, Situ Bagendit, Cibogo, and IR64, sustained evaluation through a randomized complete block design (RCBD) with three replications. The correlation analysis performed sought to determine the relationship between characters as selection criteria. The selection criteria obtained based on Pearson's correlation included plant length (PH), panicle length (PL), number of fertile grains (FG), total grains per panicle (TP), and weight of grains per plant (GWP). The result of this research identified two F7 genotypes, F7-4-21-11-23-3-2 and F7-4-21-11-23-6-11, as potential rice lines with higher grain yield than the check varieties. Multi-location-based trials and screening of resistance genes need to be carried out to determine the stability and resistance of genotypes to pest and disease attacks.

Keywords: Rice (*O. sativa* L.), breeding, potential F7 lines, yield assessment, genetic parameters

Key findings: The lowland test environment influenced the performance of some characters of F7 rice (*O. sativa* L.) lines obtained from the hybridization of rainfed and irrigated rice genotypes based on the CV_e value. The two rice genotypes F7-4-21-11-23-3-2 and F7-4-21-11-23-6-11 emerged as potential lines for better yield traits.

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the major staple food commodities in Indonesia and worldwide. However, in Indonesia, the rice need increases yearly, which correlates with the rising population. In previous years, rice production has experienced problems resulting in decreased rice yields. According to the Central Bureau of Statistics (CBS), Indonesia (2021), the national rice production was 54,415,294.22 tons in 2021, while in 2020 the rice production was 55,649,202.24 tons, showing a decline of 2.2% in production during 2021 versus 2020. The rice production decrease resulted from several factors, with one important factor being the reduction in productive agricultural land area, which decreased by 2.30% (245,470 hectares) in 2021 compared with 2020 (CBS, 2021).

Plant breeders can make efforts to overcome the problems in rice production by developing superior cultivars. Yanuar and Adiredjo (2017) assembled and studied the high-yielding rice cultivars by hybridizing the lowland genotype Cibogo and upland rice cultivar Situ Bagendit, which produced the F1 hybrids. The cross-hybridization between the upland rice cultivar Situ Bagendit and the lowland cultivar Cibogo proceeded as an effort to amass superior genotypes that can grow optimally on dry lands with higher production (Adiredjo *et al*., 2019).

The obtained F1 hybrid seeds received further assessment under field conditions using the pedigree selection method to acquire the breeding material of the F7 generation. Pedigree selection reached characterization by recording genealogies for each generation (Acquaah, 2012). From the F2 generation, various evaluation tests have also transpired to determine the genetic information of the selected rice plants. In the F2 generation, the genetic purity test took place using SSR markers involving the parental genotypes of the F1, F2, and BC1 populations (Adiredjo *et al*., 2023). No inclusion of the crosses with genetic contamination outside the parental cultivars happened in the selection. Estimation of gene action has also progressed in the F4 and F5 generations (Ardiarini *et al*., 2022).

Before the release as superior rice cultivars, the expected lines of the F7 generation need to go through a yield test stage. The yield test continued on the F7 generation because, in theory, at this phase, the plant population is already homozygous, and only a few offspring can succeed in selection using the quantitative inheritance mode (Singh *et al.*, 2021). The preliminary yield testing is the stage of assembling the potential rice genotypes to determine their yield potential and finally obtain the best genotypes before being released as superior cultivars (Syukur *et al*., 2017). The selection of the preliminary yield test location will also affect the response of the genotypes tested. Rice plants have an optimum temperature that supports their growth in the range of 25 °C–28 °C (Shrestha et al., 2022). Therefore, research on the initial yield test of potential F7 generation lines at locations with optimum temperatures, especially representative lowlands, essentially needs to be carried out as one of the stages in the assembly and selection of superior rice cultivars.

MATERIALS AND METHODS

The following research on rice (*O. sativa* L.) began from January until June 2023 in Jenggolo Village, Kepanjen District, Malang Regency, East Java, Indonesia. It covered lowlands at an altitude of ±289 masl, with a daily mean temperature of 26 °C and rainfall intensity of 235.08 mm/month.

The breeding material used in this study comprised six potential rice lines of the F7 generation (F7-4-21-11-23-3-2, F7-4-21-11-23-3-11, F7-4-21-11-23-3-12, F7-4-21-11-23-6-2, F7-4-21-11-23-6-11, and F7-4-21-11-23-6-17) and three check cultivars—Situ Bagendit, Cibogo, and IR64. Other materials used are the urea, KCl, and SP-36 fertilizers and Hopper pesticides. The study ensued in a randomized complete block design (RCBD) with nine treatments and three replications. Each experimental unit plot contained 28 plants with a spacing of 20 cm × 20 cm.

The data recording on both quantitative and qualitative characters continued. The quantitative characteristics noted were the plant height, date to harvesting, date to flowering, number of productive tillers, panicle length, fertile grains per panicle, total grains per panicle, fertile grains (%), 1000-grain weight, grain weight per hill, and grain yield per hectare. Meanwhile, the qualitative traits observed were the leaf, ligule, and auricle colors; flag leaf and rod angles; awn color; leaf surface; and lodging. The data generated from the qualitative characters incurred descriptive analysis for additional information in the form of a description of the potential lines and as support for the quantitative data. Analysis of quantitative data used the genetic parameter analysis and analysis of variance. Performing the Pearson correlation analysis helped determine the contribution of traits to crop yields. The estimation of variance utilized the following formula (Khan *et al*., 2023):

Environmental variation

Environmental variance, as formulated, used the following formula

$$se = MSe$$

Where MSe is the mean squared error, and r is the number of replications.

Genotypic variation

The genotypic variance estimation applied the following formula:

$$\sigma g = \frac{MSg\text{-}MS\varepsilon}{r}$$

Where sg is the genetic variance, MSg is the mean square of the genotype, and se is the variance that arises due to environmental factors.

Phenotypic variation

Phenotypic variance estimation can follow the formula below.

$$\sigma p = \sigma e + \sigma g$$

Where σp is the plant phenotypic variance, σg is the genetic variance, and σe is the variance that arises due to environmental factors.

The estimation of genotypic, phenotypic, and environmental coefficients used the following formula (Johnson *et al*., 1955; Nihad *et al*., 2021):

$$CVg = \frac{\sqrt{\sigma g}}{\bar{X}} \times 100\%$$

$$CVp = \frac{\sqrt{\sigma p}}{\bar{X}} \times 100\%$$

$$CVe = \frac{\sqrt{\sigma e}}{\bar{X}} \times 100\%$$

The classification of CVG, CVP, and CVE values used the classification of Sivasubramanian and Madhava (1973), with categories as low (0%–10%), moderate (10%–20%), and high (>20%) (Khan *et al*., 2023).

Heritability

The estimated value of broad-based heritability, as calculated, utilized the following formula (Falconer, 1989; Khan *et al*., 2023):

$$h^2_{bs} = \frac{\sigma g}{\sigma p}$$

Where h^2_{bs} is heritability in the broad sense, sg is the genetic variance, and sp is the phenotypic variance. After the analysis of variance, the means' further comparison employed the Duncan's multiple range test (DMRT) at a 5% level of probability.

RESULTS AND DISCUSSION

Quantitative characters

In six potential F7 lines and three cultivars of rice (*O. sativa* L.), the genetic parameters attained estimates for nine traits (Table 1). Several rice plant traits had the control of genetic factors based on the observed genetic variance and heritability. However, the traits

Table 1. Genetic parameters for various traits in rice genotypes.

Genetic parameters	PH	DH	PL	FG	TG	PFG	1000G	GWP	GY
σ_p	96.02	2.29	4.94	117.61	199.66	39.27	0.35	25.18	1.01
σ_g	93.69	0.84	4.64	96.32	93.63	-9.13	-0.07	17.91	0.72
σ_e	2.331	1.45	0.30	21.30	106.03	48.41	0.42	7.27	0.29
h^2_{bs}	0.97	0.37	0.94	0.82	0.47	-0.23	-0.21	0.71	0.71
CV_e	1.36	1.06	2.11	5.87	10.02	9.07	2.36	7.18	7.18
CV_g	8.64	0.81	8.26	12.48	9.42	3.94	0.99	11.27	11.27
CV_p	8.75	1.33	8.52	13.79	13.75	8.17	2.14	13.36	13.36

Description: PH=plant height (cm); DH=days to harvesting (DAP); PL=panicle length (cm); FG=fertile grain panicle^{-1}; TG=total number of grains panicle^{-1}; PFG=fertile grain (%); 1000G=1000 weight grains (g); GWP=grain weight panicle^{-1}; GY=grain yield (t ha^{-1}); σp=phenotypic variance; σg=genotype variance; σe=environmental variance; h^2_{bs}=broad sense heritability; CVe=coefficient of environmental variation; CVg=genotype coefficient of variation; and CVp=coefficient of variation of phenotype.

harvest age, grains per hill, fertile grain (%), and 1000-grain weight had low genetic variances. The results showed numerous traits bore considerable influences from environmental factors by showing the large environmental variances. Onuora *et al*. (2016) stated that when the PCV value is greater than the GCV (which indicates the ECV value is greater than the GCV), it shows environmental factors influencing the genotype in expressing the character. With the greater values of environmental variance than the genetic variance, the heritability value was also low. According to Syukur *et al.* (2017), the heritability was low if the value was less than 20%, quite high in the range of 20%–50%, and the highest (when more than 50%).

Two characters, namely, the percentage of fertile grain and the weight of 1000 grains, showed low heritability values (<20%) (Table 2). These two traits have negative values in estimating heritability. Negative heritability values become declared zero because they were unrealistic, even though in statistical theory, the calculation system produces positive and negative values (Steinsaltz *et al*., 2020). Therefore, the trait percentage of fertile grain and weight of 1000 grains have low heritability values due to a low genetic variance. Priyanto *et al*. (2023) mentioned that the low broad-sense heritability value was due to a low genotypic variance, and the variation that occurs might refer to environmental influences. However, there exists a consequence of using plants being selected through pedigree selection. Mathew *et al*. (2018) explained that if the genotype result of pedigree selection, the characteristics emerged with low heritability values (Effendy *et al*., 2018; Priyanto *et al*., 2023).

All six rice F7 populations showed higher plant height than the check cultivars Situ Bagendit and IR64 (Table 2). However, the four rice F7 genotypes, F7-4-21-11-23-3-2, F7-4-21-11-23-3-12, F7-4-21-11-23-6-2, and F7-4-11-21-23-6-11, have the plant height equivalent to the check cultivar Cibogo. Plant height has a relationship with lodging; the taller the plants, the easier to lodge, and eventually affects grain yield (Vergara, 1995). The four rice F7 genotypes F7-4-21-11-23-3-2, F7-4-21-11-23-6-2, F7-4-21-11-23-6-11, and F7-4-21-11-23-6-17 were notable with the same harvest and were early maturing compared with the check cultivars and reached the early maturing category, as per IRRI classification (IRRI, 2013). In rice, early maturity is one of the important traits that overcomes rice production problems and can have a harvest with higher production (Lestari and Aswidinnoor, 2007). The length of rice harvest time could have influences from various plant life cycles, as determined by genetic and environmental factors and their interactions. Vergara and Chang's (1985) findings revealed that rice genotypes with early harvest traits do not bear effects from photoperiodicity.

Table 2. Rice genotypes performance for various quantitative traits.

Genotypes	Plant height (cm)	Days to harvesting (DAP)	Panicle length (cm)	1000-grain weight (g)
F7-4-21-11-23-3-2	118.40 a	113.47 ab	28.38 a	27.57
F7-4-21-11-23-3-11	114.37 cd	113.67 a	27.12 bc	27.32
F7-4-21-11-23-3-12	117.70 a	113.90 a	25.85 d	27.62
F7-4-21-11-23-6-2	116.37 abc	113.57 ab	26.87 c	27.42
F7-4-21-11-23-6-11	116.87 ab	113.37 ab	27.97 ab	27.89
F7-4-21-11-23-6-17	113.50 c	113.43 ab	27.47 abc	27.42
Situ Bagendit	105,50 d	111.37 b	23.70 e	28.00
Cibogo	117.70 a	115.00 a	25.77 d	27.44
IR64	88.17 e	115.27 a	21.65 f	27.21

For the 1000-grain weight, the rice F7 genotypes and check cultivars showed nonsignificant differences, which confirmed recording of the genotypes with the same seed size and weight (Table 2). The results further revealed that, regarding panicle length, the five rice F7 genotypes, F7-4-21-11-23-3-2, F7-4-21-11-23-3-11, F7-4-21-11-23-6-2, F7-4-21-11-23-6-11, and F7-4-21-11-23-6-17, expressed an increased panicle length compared with the three check cultivars (Table 2). For the total number of grains per panicle, the six F7 genotypes produced more grains than the check cultivars Situ Bagendit and IR64. However, by comparing with the reference cultivar Cibogo, the panicle length of the six F7 genotypes displayed equivalent results. Past findings stated that panicle length influences the number of grains per panicle (Suprayogi *et al.*, 2021). Makarim and Suhartatik (2009) also confirmed that panicle length had a close correlation to the number of grains produced in the panicle, and the longer the panicle, the more grains developed. However, in contradiction, Zhang *et al*. (2012) reported that most of the rice cultivars with higher panicle length could not meet the production expectations because of the poor grain filling (Meng *et al*., 2016). Poor grain filling could be due to disrupted physiological processes caused by limited nutrition (Shi *et al*., 1995; Yuan, 1997; Meng *et al*., 2016), hampered grain assimilation processes (Yang *et al*., 2002; Meng *et al*., 2016), slow rate of endosperm cell division (Li *et al*., 2013), and unbalanced levels of plant growth regulatory hormones (Yang *et al*., 2003; Zhang *et al*., 2009; Meng *et al*., 2016).

The six rice F7 genotypes produced the most number of fertile grains and fertile grains per panicle versus the check cultivars Situ Bagendit and IR64; however, they displayed at par with the cultivar Cibogo for said trait (Table 3). According to Susilawati *et al*. (2010), influences on the number of grains per panicle resulted from the translocation of photosynthesis into seeds, and each genotype has a different photosynthetic capacity. According to Ayudya (2022), the number of fertile grains per panicle in the F6 genotypes directly affects the selection and has the highest selection index.

The outcomes revealed the trait of fertile grains per panicle percentage had a nonsignificant effect from all the genotypes, and the percentage of fertile grain ranged from 71.19% to 79.78% (Table 3). It showed the percentage of empty grains in the panicles was quite high. Generally, empty panicles occur if the produced panicles had no accompaniment of a rapid grain filling and ripening period (Susilawati *et al*., 2010). According to Vergara (1995), several factors influence the filling of rice grains, i.e., low light intensity, lying position, drying of leaves, and pest attack. Additionally, the rice cultivars have varied photosynthetic capacities that also impact the seed yield. Based on the results of the correlation analysis of characters against climate variables (Figure 1), one can see that the percentage of fertile grains and the number of fertile grains per panicle have no strong alterations from climate factors. Hence, it is a theory that other factors influence the value of these two characteristics.

Table 3. Rice genotypes performance for various quantitative traits.

Genotypes	Fertile grain panicle^{-1}	Total grains panicle^{-1}	Fertile grain (%)	Grain weight panicle^{-1} (g)	Grain yield (t ha^{-1})
F7-4-21-11-23-3-2	89.09 a	112.23 a	79.78	41.72 a	8.34 a
F7-4-21-11-23-3-11	76.24 b	107.03 a	71.19	37.80 a	7.56 a
F7-4-21-11-23-3-12	80.89 bc	104.75 a	77.49	37.60 a	7.52 a
F7-4-21-11-23-6-2	82.92 bc	107.36 a	77.83	39.70 a	7.94 a
F7-4-21-11-23-6-11	88.49 a	112.97 a	78.60	41.47 a	8.29 a
F7-4-21-11-23-6-17	84.49 bc	108.08 a	78.26	39.77 a	7.95 a
Situ Bagendit	62.98 c	85.47 b	74.33	31.03 b	6.21 b
Cibogo	81.68 bc	105.73 a	77.63	39.87 a	7.97 a
IR64	61.23 c	81.35 b	75.36	29.03 b	5.81 b

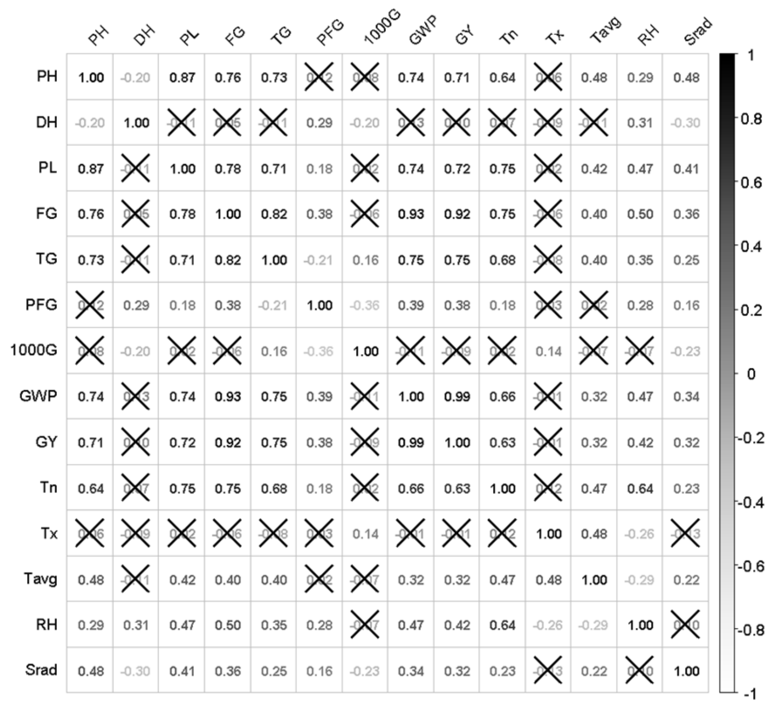

Figure 1. Correlation matrices between traits and climatic factors. Description: PH=plant height (cm); DH= days to harvesting (DAP); PL=panicle length (cm); FG=fertile grain panicle^{-1}; TG=total number of grains panicle^{-1}; PFG=fertile grain (%); 1000G=1000 weight grains (g); GWP=grain weight panicle^{-1}; GY=grain yield (t ha$^{-1)}$; Tn=minimum temperature (℃); Tx=maximum temperature (℃); Tavg=mean temperature (℃); RH=relative humidity (%); and Srad=daily solar radiation intensity (J m$^{2\ -1}$). The darker the color, the stronger the positive relationship, the fainter the color, the stronger the negative relationship.

The six F7 genotypes showed a higher grain weight per panicle than the check cultivars Situ Bagendit and IR64 (Table 3). However, by comparing the F7 rice genotypes with the cultivar Cibogo, the grain weight per panicle was nonsignificantly different. The same results were also evident from the grain yield per hectare, and the six rice F7 genotypes provided at-par yield per hectare with the check cultivar Cibogo. However, they had a higher yield than

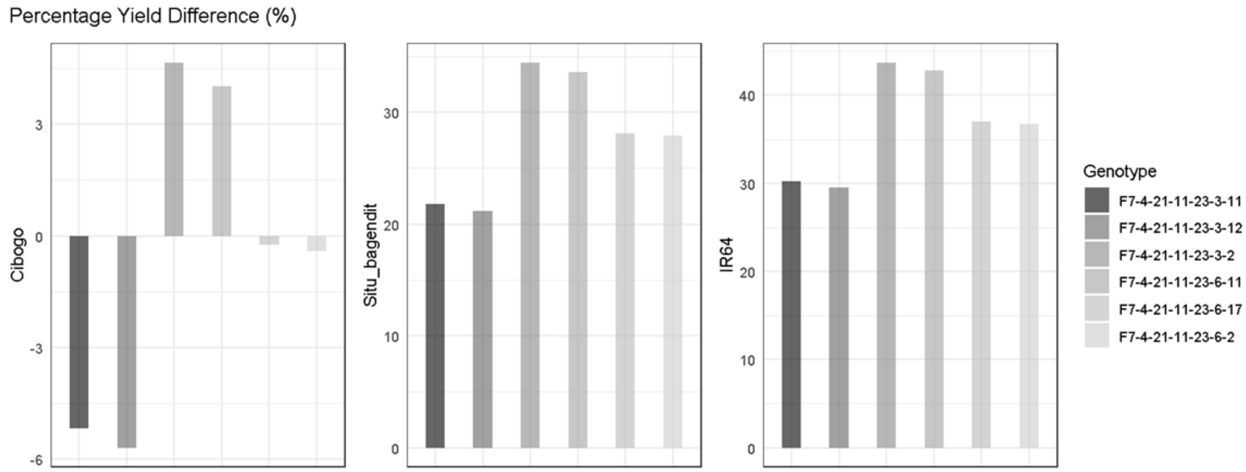

Figure 2. Grain yield differences in six potential lines and three check cultivars of rice.

the check cultivars Situ Bagendit and IR64. The F7 genotype F7-4-21-11-23-3-2 showed the highest grain yield (8.43 t ha^{-1}), while the check cultivar Cibogo produced only 7.97 t ha^{-1}. The result indicated a prospective line of hope to become a superior cultivar. Grain yield per hectare itself has influences from other characteristics, such as panicle length and the number of fertile grains per panicle. Siregar *et al*. (1998) reported that grain yield was mainly under the impact of the number of productive tillers, panicle length, percentage of full grain per panicle, and the number of fertile grains per panicle.

The yield difference between the rice F7 genotypes and check cultivars appears in Figure 2. The yield difference (%) shown by the six F7 genotypes was higher than the check cultivars Situ Bagendit and IR64. However, the two rice F7 genotypes F7-4-21-11-23-3-2 and F7-4-21-11-23-6-11 produced a higher grain yield than all the check cultivars. According to Lenaerts *et al*. (2019), the genotypes with higher yields that exceed those of standard cultivars commonly planted are one of the great successes in plant breeding programs. Therefore, these two promising lines have the potential to be developed into superior rice cultivars.

From the results of the Pearson correlation analysis (Figure 1), it is a fact that the harvest incurred influences from the characteristics of plant height, panicle length, total fertile grain, total grains per panicle, and the number of grains per plant. The percentage of fertile grain has only a small effect on the harvest. According to Falconer and Mckay (1996), characters with a strong relationship can be effective as criteria for selecting a genotype (Alsabah *et al.*, 2019). Therefore, the traits of plant height, flowering age, panicle length, number of fertile grains, total grains per panicle, and weight of grains per plant can be favorable as selection criteria together with yield.

Qualitative characters

Qualitative characters sustain control from simple genes, with minimal influences from environmental factors (Nasir, 2001). However, qualitative characters have their respective roles in supporting rice production. The leaf color attribute shown by the rice potential F7 lines and check cultivars revealed that all the tested populations have uniform leaf color under the green category, based on IRRI classification (Table 4) (IRRI, 2013). The color of the earlobes and ligula showed all rice F7 genotypes and check cultivars were uniform and colorless. According to Makarim and Suhartatik (2009), leaf ears are an essential part of the rice plant that requires describing because these two parts differentiate the rice plants from grasses. Another study also reported that leaf ears have the same role as a differentiator between grasses and rice (Mursyidin *et al.*, 2021).

Table 4. Rice genotypes performance for various qualitative traits.

Genotypes	Leaf color	Ligule color	Auricle color	Leaf surface
F7-4-21-11-23-3-2	Green	Colorless	Colorless	Rough
F7-4-21-11-23-3-11	Green	Colorless	Colorless	Rough
F7-4-21-11-23-3-12	Green	Colorless	Colorless	Rough
F7-4-21-11-23-6-2	Green	Colorless	Colorless	Rough
F7-4-21-11-23-6-11	Green	Colorless	Colorless	Rough
F7-4-21-11-23-6-17	Green	Colorless	Colorless	Rough
Situ Bagendit	Green	Colorless	Colorless	Rough
Cibogo	Green	Colorless	Colorless	Rough
IR64	Green	Colorless	Colorless	Rough

Table 5. Rice genotypes performance for various qualitative traits.

Genotypes	Flag leaf angle	Rod angle	Awn color	Lodging
F7-4-21-11-23-3-2	Erect	Erect	Straw	Intermediate
F7-4-21-11-23-3-11	Erect	Erect	Straw	Intermediate
F7-4-21-11-23-3-12	Erect	Erect	Straw	Intermediate
F7-4-21-11-23-6-2	Erect	Erect	Straw	Intermediate
F7-4-21-11-23-6-11	Erect	Erect	Straw	Intermediate
F7-4-21-11-23-6-17	Erect	Erect	Straw	Intermediate
Situ Bagendit	Erect	Erect	Straw	Intermediate
Cibogo	Erect	Erect	Straw	Intermediate
IR64	Erect	Erect	Straw	Resistance

Study findings further revealed that all the F7 rice genotypes and check cultivars showed uniform and rough leaf surfaces (Table 4). The rough leaf surface is characteristically the presence of hairs, and by touching the leaf surface, it will feel rough. As for the characteristics of flag leaf shape, all the rice F7 potential lines and check cultivars exhibited uniform and upright shapes. The erect flag leaf category showed that the angle formed between the flag leaf and the main panicle axis tended to be perpendicular. According to Kartahadimaja *et al*. (2021), the flag leaf shape had a close relation to attacks by grain-eating birds, where the upright flag leaf can cover the panicles and make it difficult for birds to land, thereby minimizing yield losses.

On the plant shape characters, all the rice F7 genotypes and check cultivars showed uniform and upright positions, with the appearance of the angle of the stem formed being estimated to be <30° (Table 5). The rice plants with an upright shape had more optimal growth due to the effectiveness of sunlight absorption in the photosynthesis process (Wahyuti *et al*., 2013). The grain color characteristics displayed by all the F7 potential lines and check cultivars were visibly uniformly clean yellow. The grain color produced was the color of the lemma and palea covering the grains (Salsabila *et al*., 2021). The grain color attribute plays an important role in rice color formation, and the red rice will produce red grains (Susilawati *et al*., 2010).

The rice lodging trait is crucial because it has a worrying impact. The paddy-yielding character detailed that the grain yield produced by the six F7 genotypes and the check cultivars Situ Bagendit and Cibogo attained the moderate category, with the occurring yield estimated to be around 41%–60% (Table 5). Meanwhile, in comparison, the cultivar IR64 had a lodging level (<20%). In addition to environmental factors, the degree of lodging sustained effects from plant height, and the taller plants easily collapse (Salassi *et al*., 2013). The cultivar IR64 has the lowest average plant height compared with other rice genotypes, and therefore, it has a lower lodging rate.

CONCLUSIONS

The estimation of genetic parameters showed that the five rice (*O. sativa* L.) traits, viz., plant height, panicle length, fertile grains per panicle, grain weight per panicle, and grain yield, had predominant control from genetic factors. However, the other four traits, namely, days to harvest, total number of grains per panicle, percentage of fertile grains, and 1000-seed weight, have considerably more effects from environmental factors. Based on the Duncan's multiple range test and Pearson correlation, the two F7 genotypes F7-4-21-11-23-3-2 and F7-4-21-11-23-6-11 emerged as potential rice lines with higher grain yield than the check cultivars. Therefore, multi-location research and screening of pest- and disease-resistance genes need to be carried out to determine the stability and resistance of the two genotypes.

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