# Yield and Blast Resistance Evaluation of Upland Rice Lines with New Plant Type Characters

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**Abstract**

The present studies were conducted to determine agronomic characters, genetic variability, broad sense heritability ($h^2_{bs}$) and blast resistance of doubled haploid rice lines and to obtain new plant type (NPT) of upland rice with high yield potential and blast resistant. The research was conducted in Bogor and Sukabumi, Indonesia started from November 2010 to June 2011. There were 14 genotypes evaluated namely the new lines of rice from anther culture (FG1-66-2-1, FG1R-108-1-1, FG1R-51-2-1, FM1-14-1-1, FM1-14-1-2, FM1-25-1-1, FM1-25-1-2, FM1-57-1-2, FM1R-32-1-1, FM1R-23-1-1, FG2-47-1-3, FM1R-19-2-4, FM2-12-1-1, FAT-4-1-2), as well as Fatmawati, Limboto and Batutegi as check varieties. The experimental design used was randomized block design (RBD). The results showed that there was variability on agronomic traits and blast resistance among lines evaluated. FG2-47-1-3 did not have complete characters of NPT, but the line had superior characteristics such as high percentage of filled grain, medium days to harvest, medium height, medium 1000-filled grain weight, stay green when harvested and high resistance to blast disease. The results also indicated that the tested population had high heritability ($h^2_{bs}$) in leaf blast and neck blast resistance, plant height, filled grain per panicle, days to harvest, number of grain per panicle and 1000-filled grain weight. They showed high variance coefficient for leaf blast and neck blast resistance, flag leaf length and percentage of filled grain.

*Keywords: new plant type, upland rice, blast resistance, heritability.*

## Introduction

Rice is staple food in Indonesia. Population growth will increase national rice consumption (Prasetyo 2008). In the year of 2000-2006, population growth rate was 1.36% with per capita consumption of rice at 137 kg. It is estimated that in 2010, 2015 and 2020 consumption of rice and a population with declining population growth rate assumption of 0.03%, respectively was 32.13 million tons with a population of 235 million, 34.12 million tons with a population of 249 and 35.97 million tons with population of 263 million inhabitants (Puslitbangtan 2007).

Increase in national rice production must be continually pursued. One of the effort to increase national rice production is the use of dry land to grow upland rice so as to support national food security (Puslitbangtan 2007). Indonesia has 11.6 million ha of dry land (BPS 2005). Dry land used for planting upland rice in 2010 reached 1.13 million ha (Deptan 2011), so there are still opportunities to expand the area of upland rice cropping. Upland rice production reached 3.45 million tons with yield of 3.05 tons/ha (Deptan 2011). Contribution of upland rice to the national rice production is still low at 5% (Prasetyo 2008).

Increased productivity of upland rice can be done by developing a new plant type (NPT) of upland rice lines. NPT ideotype characters desired, among others, are plant height <150 cm, number of productive tillers > 6, number of grain per panicle > 150, short growth period (105-124 days), good filled grain (> 75%), 1000-filled grain weight more than 28 g (Herawati 2010).

Based on previous research, rice lines were obtained from crosses of a new plat type of lowland rice Famawati with local upland rice varieties from the island of Buru namely Fulan Telo Gawa (FTG) and Fulan Telo Mihat (FTM) through anther culture (Safitri 2010). Lines need to be further evaluated both morphological and agronomic characters/ performance and resistance to blast disease.

Blast disease is caused by fungus *Pyricularia grisea*. The disease can reduce the productivity of upland rice between 11-50% (Beker *at al*. 1997; Scardaci *et al*. 1997). Fungus *Pyricularia grisea* infects leaves at vegetative stage, called leaf blast, while in the generative stage, the pathogen also infects the panicle neck, called neck blast (BB Biogen 2009).

The present studies were conducted to obtain information on performance of agronomic characters and resistance to leaf blast and neck blast in the new rice lines. In addition, this study was also aimed to select a new plant type of upland rice lines with high yield and resistant to blast disease.

**Materials and Methods**

The research was conducted in Babakan Experiment Station, University Farm, Bogor Agricultural University and in the village of Bojong, Cikembar Sub-District, Sukabumi District, West Jawa, Indonesia (endemic blast region) from November 2010 to April 2011. The genetic materials were 15 doubled haploid upland rice lines obtained from anther culture of F1, crosses between Fatmawati and Fulan Telo Mihat or Fulan Telo Gawa (Safitri 2010). Fatmawati, Batutegi and Limboto were used as a check varieties.

This study used a randomized blocked design with lines as treatment and consisted of 3 replicates. Experimental unit in Bogor was done in the form of a plot of 3 x 3.6 m. Three seeds were planted per hill with spacing of 30 x 20 cm. In Sukabumi, each replicate was 10 x 2 m. One seed was planted per hill with spacing of 20 x 10 cm. Fertilizer use were 10 tons of manure/ha, 200 kg of Urea/ ha (given: 20% age 1 week, 40% at age 4 weeks and 7 weeks), 100 kg/ha of KCl and 100 kg/ha of SP36. Maintenance was performed in accordance with the conditions and crop needs in the field.

Observations were made on 5 plants per plot on variables: plant height, number of productive tillers, days to harvest, total grain per panicle, percentage of filled grain, 1000-filled grain weight, productivity, the scale and intensity of leaf blast and neck blast disease. The data obtained were analyzed by F test, if significantly different then followed by Dunnett test on a level of significance 5%, range estimation and analysis component of the correlation between characters.

The intensity of leaf blast disease was calculated with the formula: $I = \Sigma (n \times v) / (N \times V) \times 100\%$, where I = intensity of disease, n = number of plants infected, v = scale of plant infected, N = total number of plant observed, V = the highest scale of blast disease (9) (IRRI 1996). Resistance to blast disease were classified into resistant, if $I \leq 10\%$ and susceptible, if $I > 10\%$. Observation of the panicle neck blast was performed at harvest which includes the scale and intensity of the disease. The intensity was calculated by: $I = \Sigma n / N \times 100\%$, where I = intensity of blast disease, n = number of panicles infected, N = number of panicles observed. The scale of the disease was determined based on the evaluation system on panicle neck blast disease from IRRI (1996) as follows: 0 = no symptom, 1 = infection of less than 5%, 3 = 5-10% infected, 5 = 11-25% infected, 7 = 26-50% infected, 9 = more than 50% infected. Panicle neck blast resistance were classified into resistant (score 0-1), moderately resistant (score 3-4), moderately susceptible (score 5-6) and susceptible (score 7-9).

**Results and Discussion**

The variance analysis showed that the genotype effect was significant on all characters observed. This indicated that there were differences between doubled haploid lines of upland rice. The coefficient of variability (CV) ranged between 2.5 and 43.6% (Table 1). Plant height ranged from 73.8 to 124.0 cm (Table 1). Higher plant meets the criteria as a new plant type of upland rice lines. According to Herawati (2010) and Abdullah *et al*. (2005), height of new plant type of upland rice is under 150 cm and for a new plant type of lowland rice is 80-100 cm. The height of some lines tested (FG1R-108-1-1, FG1R-51-2-1, FM1-14-1-1, FM1-57-1-2-32-FM1R 1-1 FG2-47-1-3) were significantly different from and were higher than Fatmawati (Table 1). Nonetheless, plant height still meets the general criteria for the plant height of new types of upland rice lines.

The number of productive tillers of 14 lines tested ranged from 6.5-15.5. According to Peng *et al*. (2008), the number of productive tillers are ideal for a new pant type of rice (NPT) is 10-15 for lowland rice, while according to Herawati (2010) the number of productive tillers for a new plant type of upland rice lines is > 6. Fatmawati has the potential to produce 6-14 tillers. The number of tillers Fatmawati in upland conditions conducted in this study was 13.

Table 1. Agronomic performance of doubled haploid upland rice lines

| Lines | PH | NPT | DH | TS | FG | PFG | B1000 | YP |
|---|---|---|---|---|---|---|---|---|
| FG1-66-2-1 | 91.2 | 11.8 | 127.7 | 177.6 | 59.4 | 33.3 | 29.7$^{e+}$ | 0.52 |
| FG1R-108-1-1 | 124.0$^{a+}$ | 6.5$^{a-}$ | 130.3 | 137.4$^{e-}$ | 11.6$^{e-}$ | 17.1 | 26.3 | 0.24$^{e-}$ |
| FG1R-51-2-1 | 116.6$^{a+}$ | 7.9 | 130.0 | 154.0 | 7.5$^{e-}$ | 4.5$^{e-}$ | 29.3$^{e+}$ | 0.08$^{e-}$ |
| FM1-14-1-1 | 102.7$^{a+}$ | 8.3 | 126.7 | 114.7$^{e-}$ | 18.4$^{e-}$ | 15.0 | 30.3$^{e+}$ | 0.41 |
| FM1-14-1-2 | 97.6 | 10.4 | 128.3 | 100.5$^{e-}$ | 13.0$^{e-}$ | 11.7$^{e-}$ | 29.3$^{e+}$ | 0.26$^{e-}$ |
| FM1-25-1-1 | 90.4 | 8.4 | 134.3$^{a+}$ | 122.3$^{e-}$ | 5.4$^{e-}$ | 3.9$^{e-}$ | 29.0$^{e+}$ | 0.12$^{e-}$ |
| FM1-25-1-2 | 93.2 | 8.1 | 134.7$^{a+}$ | 115.1$^{e-}$ | 15.0$^{e-}$ | 2.1 | 25.3 | 0.65 |
| FM1-57-1-2 | 112.1$^{a+}$ | 11.3 | 134.3$^{a+}$ | 133.6$^{e-}$ | 29.5$^{e-}$ | 8.3$^{e-}$ | 31.0$^{e+}$ | 1.48 |
| FM1R-32-1-1 | 118.7$^{a+}$ | 10.7 | 130.0 | 128.7$^{e-}$ | 46.4 | 37.1 | 33.3$^{e+}$ | 1.06 |
| FM1R-23-1-1 | 77.4 | 11.3 | 131.3$^{a+}$ | 115.8$^{e-}$ | 2.1$^{e-}$ | 2.3$^{e-}$ | 25.3 | 0.08$^{e-}$ |
| FG2-47-1-3 | 110.3$^{a+}$ | 15.5 | 128.0 | 118.4$^{e-}$ | 80.1 | 68.3 | 25.3 | 2.00 |
| FM1R-19-2-4 | 73.8 | 13.3 | 128.3 | 69.0$^{e-}$ | 2.5$^{e-}$ | 32.8$^{e-}$ | 25.7 | 0.04$^{e-}$ |
| FM2-12-1-1 | 94.0 | 11.2 | 122.0 | 61.3$^{e-}$ | 22.3$^{e-}$ | 34.8 | 23.3$^{e+}$ | 0.31 |
| FAT-4-1-2 | 79.1 | 11.1 | 128.3 | 112.7$^{e-}$ | 40.0 | 34.8 | 28.3 | 0.72 |
| Fatmawati(a) | 84.6 | 13.0 | 123.3 | 102.6 | 11.5 | 10.0 | 25.7 | 0.31 |
| Batutegi (e) | 118.6 | 10.7 | 126.0 | 213.3 | 114.2 | 53.8 | 26.3 | 1.88 |
| CV (%) | 6.6 | 12.5 | 2.5 | 9.9 | 43.6 | 40.0 | 3.4 | 26.3 |

Note: Numbers followed by the letters a+ and a- column differ significantly higher and differ or lower with Fatmawati. Numbers and e+ e- is significantly different higher or lower than Batutegi based on the Dunnett test at significant level of 5%. PH = plant height, NPT = Number of productive tillers, DH = days to harvest. TS = Total spikelet, FG = number of filled grain, PFG = Percentage of filled grain, B1000 = 1000-filled grain weight, YP = Yield potential (tons/ha), CV = coefficient of variability.

According to Herawati (2010), the days to harvest of new plant type of upland rice ranged from 105 to 124 days. Days to harvest of the lines tested ranged between 122-134.3 days. The line that meet the criteria was FM2-12-1-1. Fatmawati variety showed 123.3 days to harvest. Some of the lines tested (FM2-25-1-1, FM1-25-1-2, FM1-57-1-2, FM1R-23-1-1) had significantly different days to harvest and were longer than that of Fatmawati.

Batutegi was a variety with the highest number of spikelet per panicle (213.3 spikelets), but only had percentage of filled grain of 53.8 percent. The number of spikelet per panicle of the lines tested ranged between 61.3-177. Lines with the highest total number of spikelets was FG1-66-2-1 (177), but only 59.4 filled grain per panicle, that was 33.3%. Despite of only having a total number of spikelet 118.4, FG2-47-1-3 has the highest percentage of filled grain. According to Herawati (2010) the number of spikelet per panicle of NPT upland rice is more than 150 per panicle. Based on the number of spikelet per panicle, only FM2-12-1-1 and FG1R-51-2-1 meets the criteria. However, they had low percentage of filled grain. Weight of 1000 grain of rice ranged from 23.3 to 33.3 g

(Table 1). Variety has comparable weight of 1000 grain, ranging from 25.7 and 26.3 g. Of the 15 lines tested, 8 lines have weight of 1000 grain had more than 28 g (Herawati 2010) (Table 1).

Yield of 14 lines tested ranged from 0.04 to 2.00 tons/ha. Yield of varieties were 0.31 and 1.88 tons/ha. Batutegi had the highest yield among the check varieties (1.88 tons/ha). There were 3 lines having yield of more than one ton/ha i.e. FG2-47-1-3 (2.00 tons), FM1-57-1-2 (1.48 tons) and FM1R-32-1-1 (1.06 tons) (Table 1). The low yield of the lines and check varieties was due to blast and bacterial leaf blight and scarce rain during the reproductive period.

Based on the criteria of CGV, then there are two characters that have relatively high CGV, namely plant height and intensity of neck blast disease; two characters have the medium CGV i.e. the number of grain per panicle and the percentage of filled grain and number of filled grain per panicle; and several other characters have low CGV. Murdaningsih *et al*. (1990) stated that low CGV showed rather low genetic variability of the characters and was classified as narrow, while the medium and high value CGV were classed as broad genetic variability. Thus there were 4 characters that have broad genetic variability, and six have a narrow genetic variability.

Broad sense heritability value of the characters observed ranged from 33.4-91.2% (Table 2). According to Stanfield (1983), broad sense heritability values can be grouped into three high heritability ($0.50 < h^2 < 1.00$), medium heritability ($0.20 < h^2 \leq 0.50$) and low heritability ($h^2 < 0.20$). Based on the heritability values there are two characters that have moderate heritability (20-50%), i.e. the number of productive tillers and yield potential. another character has a heritability of 50% (Table 3). This means that agronomic characters were controlled by genetic factors more than environmental factors. Selection will be effectively carried out for characters with high heritability value.

Table 2. Variance components, heritability and genetic variability coefficient new plant type of upland rice lines

| | Characters | $\sigma^2_g$ | $\sigma^2 p$ | $\sigma^2 e$ | $h^2_{bs}$(%) | CGV (%) |
|---|---|---|---|---|---|---|
| 1. | Plant height | 315.9 | 357.4 | 41.4 | 88.4 | 17.0 |
| 2. | Days to harvest | 18.8 | 29.1 | 10.4 | 64.4 | 3.8 |
| 3. | Number of productive tillers | 0.1 | 0.3 | 0.2 | 44.3 | 2.0 |
| 4. | Number of filled grain per panicle | 5.6 | 9.7 | 4.1 | 57.5 | 10.0 |
| 5. | Number of spikelet per panicle | 3.0 | 4.1 | 1.1 | 73.0 | 5.3 |
| 6. | Percentage of filled grain | 3.7 | 6.8 | 3.1 | 55.0 | 9.2 |
| 7. | The 1000-filled grain weight | 9.0 | 9.9 | 0.9 | 91.2 | 5.7 |
| 8. | Yield | 0.04 | 0.1 | 0.1 | 33.4 | 1.9 |
| 9. | Intensity of leaf blast disease | 3.4 | 3.6 | 0.5 | 95.7 | 8.4 |
| 10. | Intensity of neck blast disease | 12.4 | 13.2 | 2.2 | 94.4 | 15.0 |

Description: $\sigma^2 g$ =Genetic variance, $\sigma^2 p$ =Phenotypic variance , $h^2 bs$ = broad sense heritability, CGV = Coefficient of genetic variance .

Line FM2-12-1-2 was blast-resistant but only had yield potential of 0.31 ton per ha. The line was not tolerant to drought. FG2-47-1-3 line was resistant to leaf blast and neck blast and had the highest number of productive tillers than all other varieties and lines tested, thus the yield of FG2-47-13 was also the highest (2 tons/ha). There were ten other lines having yield less than one ton. Low yield tons was due to low resistance of the lines to leaf blast and neck blast and drought during reproductive period (Table 3 Location in Bogor).

Based on Dunnett tests the intensity of leaf blast disease in the endemic area in Sukabumi, of 15 lines tested, there were two lines showing intensity of leaf blast disease not significantly different from control resistant (Limboto), namely FG2-47-1-3 and FM2-33-1-1 (Table 3). Panicle blast resistance of the 15 lines tested showed that the lines with intensity of neck blast disease not different from controls resistant (Limboto) were FM1-25-1-1, FM1-25-1-2, FG2-47-1 -3, FM2-12-1-1, and FAT-4-1-2 (Table 3). Line showing both resistance to leaf blast and neck blast was FG2-47-13.

Table 3. The scale and intensity of leaf blast and neck blast in lines of upland rice in Bogor and Sukabumi

| Lines | Bogor | | | | Sukabumi | | | |
|---|---|---|---|---|---|---|---|---|
| | Leaf Blast | | Neck Blast | | Leaf Blast | | Neck Blast | |
| | S | I (%) | S | I (%) | S | I (%) | S | I (%) |
| FG1-66-2-1 | 5 | 17.4$^{aR}$ | 9 | 86.3$^{aR}$ | 7 | 38.0$^{aR}$ | 9 | 74.1$^{aR}$ |
| FG1R-108-1-1 | 5 | 12.6$^{aR}$ | 9 | 63.3$^{aR}$ | 5 | 23.4$^{aR}$ | 5 | 23.5$^{R}$ |
| FG1R-51-2-1 | 5 | 38.5$^{aR}$ | 9 | 85.0$^{aR}$ | 5 | 25.4$^{aR}$ | 7 | 35.0$^{aR}$ |
| FM1-14-1-1 | 7 | 57.8$^{aR}$ | 9 | 97.7$^{aR}$ | 7 | 55.5$^{aR}$ | 9 | 87.8$^{aR}$ |
| FM1-14-1-2 | 7 | 84.8$^{aR}$ | 9 | 94.7$^{aR}$ | 7 | 44.8$^{aR}$ | 9 | 100.0$^{aR}$ |
| FM1-25-1-1 | 3 | 5.6$^{T}$ | 9 | 53.0$^{aR}$ | 5 | 16.2$^{aR}$ | 5 | 16.8$^{R}$ |
| FM1-25-1-2 | 1 | 2.9$^{T}$ | 9 | 73.7$^{aR}$ | 5 | 19.5$^{aR}$ | 5 | 13.2$^{R}$ |
| FM1-57-1-2 | 3 | 4.1$^{T}$ | 5 | 14.7$^{R}$ | 7 | 53.2$^{aR}$ | 9 | 64.4$^{aR}$ |
| FM1R-32-1-1 | 5 | 45.2$^{a}$ | 9 | 64.7$^{aR}$ | 5 | 28.7$^{aR}$ | 7 | 28.9$^{R}$ |
| FM1R-23-1-1 | 7 | 50.0$^{a}$ | 9 | 80.7$^{aR}$ | 5 | 29.6$^{aR}$ | 9 | 88.4$^{aR}$ |
| FG2-47-1-3 | 0 | 0.0$^{T}$ | 1 | 3.0$^{T}$ | 3 | 7.8$^{T}$ | 3 | 5.5$^{MT}$ |
| FM1R-19-2-4 | 7 | 71.5$^{a}$ | 7 | 32.7$^{R}$ | 9 | 62.6$^{aR}$ | 9 | 96.3$^{aR}$ |
| FM2-12-1-1 | 1 | 1.1$^{T}$ | 3 | 6.0$^{MT}$ | 9 | 66.8$^{aR}$ | 5 | 18.4$^{R}$ |
| FAT-4-1-2 | 5 | 20.0$^{aR}$ | 7 | 49.7$^{R}$ | 7 | 34.1$^{aR}$ | 1 | 2.3$^{T}$ |
| FM2-33-1-1 | - | - | - | - | 3 | 7.5$^{T}$ | 9 | 77.5$^{aR}$ |
| Limboto (a) | 0 | 0.0$^{T}$ | 1 | 3.7$^{T}$ | 3 | 4.8$^{T}$ | 1 | 0.0$^{T}$ |

Note: Figures followed by letter (a) showed higher intensity of blast disease than Limboto (resistant variety), based on the Dunnett test on a significant level of 5%. I = intensity of the blast disease, T = resistant, R = Susceptible, MT = Moderate resistant, MR = Moderate susceptible.

## Conclusions

There was variability on agronomic traits and blast resistance among the lines evaluated. FG2-47-1-3 did not have complete characters of NPT, but the line had superior characteristics such as high percentage of filled grain, medium days to harvest, medium height, medium 1000-filled grain weight, stay green when harvested and high resistance to blast disease. The population had high heritability ($h^2_{bs}$) in leaf blast and neck blast resistance, plant height, filled grain per panicle, days to harvest, number of grain per panicle and 1000-filled grain weight. They showed high variance coefficient for leaf blast and neck blast resistance, flag leaf length and percentage of filled grain.

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