Agronomic Performance and Selection of Doubled-Haploid Rice Lines for Rainfed Lowland Paddy Field

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Abstract

Rainfed lowland rice cultivation is an alternative to increase national rice production. Breeding of high yielding rice varieties suitable for rainfed lowland condition can be accelerated by using doubled-haploid (DH) as genetic materials. This study aimed at obtaining information on the agronomic performance including yields in several DH rice lines and selecting DH lines suitable for rainfed lowland paddy field. The experimental design used was a Randomized Complete Block Design with 3 replications. The treatment was thirty DH lines and 4 check varieties namely RJ31 Ciperang, RJ32 Inpari 18, RJ33 Inpari 40, and RJ43 Inpari 41. The results showed that there were variability in all agronomic performances, i.e., plant height, number of tillers, days to heading and to harvest, panicle length, number of filled and empty grains, 1000-grain weight and grain yield. The DH lines, namely RJ19 DR8-43-3-1 and RJ25 DR10-14-1-1, gave the same productivity as 4 check varieties. Index selection showed that twelve DH lines with medium number of productive tillers, early maturing, and productivity of more than 4.40 tons.ha⁻¹ were selected for further evaluation.

Keywords: Doubled-haploid, rainfed rice, selection index, yield component.

Introduction

Rice (Oryza sativa L.) is the main staple food for most Indonesian and Asian people. Rice has been cultivated for a long time in Indonesia. Preserved ancient botanical evidence in the form of rice phytoliths has confirmed that people farmed domesticated rice in the interior of Sulawesi Island, Indonesia, by at least 3,500 years ago (Deng et al., 2020). Recently, national rice consumption reaches 98.40 kg.capita⁻¹.year⁻¹ with a population of approximately 252,165,000 people (BPS, 2019). The increasing population of Indonesia can be used as an indication that the need for rice will also increase. Between 2010-2014, the increase of Indonesia's population was 1.40% per year, thus Indonesia's rice needs will reach for more than 70 million tons in the year of 2025 (BPS, 2015).

An effort to increase rice production in Indonesia is generally prioritized for land with irrigation facilities, rice paddies where water is always available at every season. The level of national production has not yet been fulfilled and there is even a shortage due to drought, weeds, pests and diseases, and natural disasters such as floods (Rahayu and Harjoso, 2010). Rice can be cultivated in rainfed fields. The development of rainfed lowland rice lines is one of the efforts, programs, or strategies to increase national rice production, in addition to irrigated and dry land.

The problems of productivity, drought tolerance, and short duration rice, among others, can be overcome by plant breeding activities to get the desired lines. Obtaining these lines can be done with conventional breeding or anther culture. According to Dewi and Purwoko (2001; 2011) breeding carried out conventionally takes a very long time from 8 to 10 generations. Shortening of pure line development time can be done by utilizing the haploid system through anther culture technique. It is expected that the process of obtaining pure lines as fully homozygous lines (doubled-haploid/DH) is accelerated by only one to two generations. Thus, it can increase efficiency of the selection process and accelerate the acquisition of varieties for release as well as saving costs, time, and labor (Dewi and Purwoko, 2012; Mishra and Rao, 2016; Purwoko, 2017).

New improved varieties can be determined by the agronomic performance (phenotypic appearance) of
a line. The quantitative character of genotypes can vary from one environment to another. A variety that is consistent with high yields in all environments is generally the desired genotype in breeding programs (Pabendon and Takdir, 2000). Plant breeding techniques are not only applied to the development of high yielding varieties but also the ability of varieties to adapt in various environments (Mulusew et al., 2009; Akter, 2014). Estimation of plant adaptation in various locations and the magnitude of the influence of interactions in the typology of land: biophysical (climate specifically), edaphic and biotic diversity (Sitaresmi et al., 2012) in a good agroecological environment is one technique for obtaining superior varieties from several rice lines tested. Munarso et al. (2010) stated that to identify stable and high yielding genotypes, evaluation in several target production environments should be conducted.

In previous research, Dewi et al. (2017) obtained 275 DH rice lines by using anther culture of F1 derived from crossing of parents that had high yield and drought tolerance characters. Those DH lines were then evaluated based on their agronomic characters. The results showed high genetic variability as well as broad sense heritability (more than 90%) for all variables tested. Anther culture could generate high genetic variability for further selection (Syafi et al., 2018). In this study 30 DH lines were evaluated for their agronomic performance. Then, potential DH lines suitable for rainfed lowland paddy fields were selected.

Material and Methods

This research was carried out at Sukamandi Rice Field Experiment Station, West Java, The Indonesian Center for Rice Research, from May to September 2019.

Plant Materials

Genetic material used in this study were 34 genotypes, i.e., 30 doubled-haploid (DH) rice lines, designated as RJ1 to RJ30, and 4 checks varieties, designated as RJ31 to RJ34 (Table 1). The doubled-haploid plants obtained from anther culture of 6 F1s derived from Inpari 18/B12825E-TB-1-25//Gajah Mungkur (DR7), Inpari18/IR87795-14-11- B- SKI- 12//Gajah Mungkur (DR8), Inpari 18/IR83140-B-11-B/Gajah Mungkur (DR9), Inpari 22/IR87705-14-11-B-SKI-12// Gajah Mungkur (DR10), Inpari 22/IR83140- B-11- B// Gajah Mungkur (DR11), and Inpago 8/B12825E-TB-1-25//Gajah Mungkur (DR12). Check varieties used were Ciherang, Inpari 18, Inpari 40, and Inpari 41. Ciherang is a mega-variety, while the other three are newly released lowland rice varieties adaptive to rainfed paddy field.

Planting and Harvesting

For each line, seeds were sowed in two 0.5 m long grooves with a distance between lines 10 cm. Land preparation involved clearing, ploughing, and harrowing. Transplanting was done by planting 18 day-old rice seedlings, 2 to 3 seedlings for each hill. Plant spacing used was 25 cm x 25 cm, so that in each plot there were 8 rows with 20 hills for each row. Fertilization was done by giving NPK in the form of Urea (250 kg.ha⁻¹), KCl (150 kg.ha⁻¹), and SP36 (150 kg.ha⁻¹). Fertilizers were given in three stages. The first fertilization was carried out at transplanting by giving Urea 83.3 g.plot⁻¹, KCl 150 g.plot⁻¹, and SP36 150 g.plot⁻¹. The second fertilization was carried out at 4 weeks after planting (WAP) by giving urea 83.3 g.plot⁻¹. The last fertilization was carried out at 8 WAP or during flowering stage by giving Urea 83.3 g.plot⁻¹. Maintenance includes weeding and controlling plant pests and diseases. Weeding was done intensively when the plant was in the vegetative and reproductive phases. Pest and disease control was carried out by mechanical and chemical methods. In mechanical method, pest was killed directly or the environment was made unsuitable for it. For example, traps for pest animals and insects; or barriers such as screens or fences to keep animals and insects out, while in chemical control, chemical pesticides are applied to protect plants from pests and diseases. Harvesting was carried out when 90% of rice panicles in one plot turned yellow. Seeds were harvested to estimate grain yield per plot. The grains were sun-dried for approximately 3 to 4 days to reach ± 14% moisture content as measured by grain moisture tester DMC550 and later converted to dry grain yield per hectare (ton.ha⁻¹).

Experimental Design and Data Collection

The experimental design used was a completely randomized complete block design (RCBD) in the form of genotypes as a treatment (Table 1) which was repeated three times. The experimental unit was a 2 m x 5 m rice plot.

Observations and measurements of the yield components were carried out on 3 hills for all lines tested. The agronomic characters observed according to Standard Evaluation System for Rice from IRRI (2013) were as follows:

1. Vegetative plant height (cm) was measured from ground level to the tip of the highest leaf. This character was observed at 45 days after planting.
2. Generative plant height (cm) was measured from ground level to the longest panicle tip. This character was observed before harvest.

3. Number of productive tillers (tillers/hill) was measured before harvest by counting tillers that produce panicles.

4. The days to heading was calculated from the days of sowing until 50% of rice panicle in a plot was fully visible.

5. The days to harvest was calculated from the days of sowing to the days when 90% of rice panicles in one plot turned yellow.

6. Panicle length (cm) was measured from the panicle neck to the panicle tip of each panicle.

7. The number of filled grains per panicle (grains) was observed by counting the number of filled grains in each panicle.

8. The number of empty grains per panicle (grains) was observed by counting the number of empty grains in each panicle.

9. Total number of grains per panicle (grains) was observed by counting the number of grains in each panicle.

10. Percentage of unfilled grains per panicle (%), was obtained by comparing the number of unfilled grains per panicle to the number of grains per panicle then multiplying by one hundred.

11. Percentage of filled grains per panicle (%), was obtained by comparing the number of filled grains per panicle to the number of grains per panicle then multiplying by one hundred.

12. Weight of 1,000 grains (g), was done by weighing 1,000 filled grains with ± 14% moisture content.

13. Productivity (tons.ha⁻¹) was calculated using the formula: \( \frac{(160,000 \text{ hills.ha}^{-1} / \text{number of hills harvested per plot}) \times \text{grain yield per plot (kg)}}{1,000} \)

### Data Analyses

Data obtained was analyzed by the normality test, if the tested trait distributed normally then continued with the analysis of variance. Furthermore, if the F test was significant, then Duncan’s multiple range test was performed (Gomez and Gomez, 1984). Selection index was used to select genotypes suitable for further yield trials in rainfed lowland environment. Several agronomic important traits representing yield and yield components were chosen simultaneously and economic weightage was given to the phenotypic values of each trait in such a way that expected gain in aggregate genotypic value would be maximized (Ramos et al., 2014; Gazal et al., 2017). Determination of the selection index were conducted based on Falconer and Mackay (1996) as follows:

\[
I = b_1X_1 + b_2X_2 + b_3X_3 + \ldots + b_nX_n
\]

where:

- \( I \) is the selection index
- \( b_i \) is the weight of the variable-\( n \)
- \( X_i \) is a standardized phenotype value (\( z \)) for variable-\( n \)

\[
z = \frac{x - \bar{x}}{s}
\]

- \( x \) is the means of each genotype
- \( \bar{x} \) is the means of the variable
- \( s \) is the standard deviation of the variable

Then, the I values were ranked and used to select the best lines. The analysis of variance and the construction of the weighted selection index were carried out using SAS 9.0 and STAR programs.

### Table 1. Lines and check varieties used in the experiment

| DH lines | DH lines | DH lines | Check varieties |
|----------|----------|----------|-----------------|
| RJ1 DR7-3-4-1 | RJ11 DR7-69-1-3 | RJ21 DR9-11-1-1 | RJ31 Cihang |
| RJ2 DR7-7-6-1 | RJ12 DR7-69-1-4 | RJ22 DR9-11-1-2 | RJ32 Inpari 18 |
| RJ3 DR7-26-3-1 | RJ13 DR7-95-1-1 | RJ23 DR9-58-1-1 | RJ33 Inpari 40 |
| RJ4 DR7-31-2-1 | RJ14 DR8-18-1-1 | RJ24 DR9-69-2-2 | RJ34 Inpari 41 |
| RJ5 DR7-35-1-1 | RJ15 DR8-20-1-1 | RJ25 DR10-14-1-1 |
| RJ6 DR7-37-1-1 | RJ16 DR8-23-2-3 | RJ26 DR10-26-1-1 |
| RJ7 DR7-43-1-5 | RJ17 DR8-31-1-1 | RJ27 DR10-27-3-1 |
| RJ8 DR7-44-1-2 | RJ18 DR8-32-2-1 | RJ28 DR10-42-1-1 |
| RJ9 DR7-67-2-1 | RJ19 DR8-43-3-1 | RJ29 DR11-36-1-1 |
| RJ10 DR7-69-1-1 | RJ20 DR9-4-1-1 | RJ30 DR12-52-2-1 |

Note: Inpari 18/B12825E-TB-1-25/Gajah Mungkur (DR7), Inpari 18/IR87795-14-11-B- SKI-12/Gajah Mungkur (DR8), Inpari 18/IR83140-B-11-B/Gajah Mungkur (DR9), Inpari 22/IR87705-14-11-B-SKI-12/Gajah mungkur (DR10), Inpari 22/IR83140- B-11- B/Gajah Mungkur (DR11), and Inpago 8/B12825E-TB-1-25/Gajah Mungkur (DR12)
Results and Discussion

Agronomic Characters of Doubled-Haploid Lines

The agronomic performance of DH rice lines showed different responses. This result can be seen in the recapitulation of variance observed in 12 characters (Table 2). Genotypes have a significant effect on all agronomic traits observed, except for the number of grains per panicle and the percentage of filled grains per panicle. The analysis of variance in Table 2 shows the character such as days to harvest has the lowest coefficient of variation (CV) value, while the number of empty grains has the highest CV value. The CV is the ratio of the standard deviation to the mean. When we are presented with estimated values, the CV relates the standard deviation of the estimate to the value of this estimate. However, the magnitude of the CV value depends on the experimental, plant, and observed factors. The lower the value of the CV, the more precise the estimate, so that it will reduce the error of the experiment (Gomez and Gomez, 1984).

Plant height character was measured at vegetative and reproductive stages. The average vegetative plant height of 34 rice genotypes ranged from 65.4-115.7 cm, while for reproductive plant height ranged from 75.6-141.9 cm (Table 3). Vegetative plant height will increase until the plant reached the reproductive stage. According to Rachmawati and Retnaningrum (2013), plant height increase is influenced by the availability of water and nutrients. Plant height at reproductive stage is one of the important criteria in selection process because it is related to the ease of maintenance and harvesting process. Tall rice plants (> 125 cm) are very easy to lodge and lodging can cause a decrease in grain yield, while the short one (< 80 cm) is relatively difficult for farmers to harvest. Therefore, plant height at reproductive stage is also an important character to farmers' acceptance of new varieties (Dewi et al., 2015). In general, according to Akbar et al. (2018) intermediate plant height (90-124 cm) was categorized as a good agronomic character for rainfed rice.

The average number of productive tillers ranged from 11.6 to 35.2 tillers per hill (Table 3). From this experiment, there is one DH line, RJ23DR9-58-1-1, that has a desirable number of productive tillers (35 tillers per hill), 6 DH lines have an acceptable number of productive tillers (20-25 tiller per hill), and the rest have medium number of productive tillers (10-19 tillers per hill). All DH lines, except for RJ23DR9-58-1-1 line, have non-significantly different number of productive tillers with the check varieties for rainfed lowland, i.e. Inpari 18, Inpari 40 and Inpari 41. The number of tillers has been reported to have a positive association with plant biomass and economic yields in rice (Wang et al., 2017). Besides the genetic and environmental conditions, the number of rice tillers is strongly influenced by age of seedling at transplanting time and plant spacing which will also determine its population density (Donggulo et al., 2017). Especially for rice, the number of productive tillers often became the main character in the selection process because it directly influences rice yields through the number of panicles, the number of grains, and filled grains per panicle (Fukushima, 2019). However, the large number of productive tillers can result in the non-synchronized panicle maturity, thus causing the quality of rice to decline (Abdullah et al., 2008).

Table 2. Summary of statistical analyses on the influence of genotypes on agronomic characters

| Variables                              | Mean Square | F-value | CV (%) |
|----------------------------------------|-------------|---------|--------|
| Vegetative plant height (VPH)          | 443.80      | 9.56**  | 8.20   |
| Generative plant height (GPH)          | 877.81      | 34.74** | 5.10   |
| Number of productive tillers (NPT)     | 65.32       | 1.55*   | 13.30  |
| Days to 50% flowering (DTF)            | 69.10       | 20.79** | 2.20   |
| Days to harvest (DTH)                  | 35.29       | 11.05** | 1.60   |
| Panicle Length (PL)                    | 6.10        | 4.90**  | 4.80   |
| Number of filled grains per panicle (NFG) | 154.21     | 2.57**  | 16.10  |
| Number of unfilled grains per panicle (NUG) | 959.14     | 4.36**  | 20.20  |
| Number of grains per panicle (NTG)     | 181.86      | 1.89ns  | 13.70  |
| % Filled grain (%FG)                   | 522.40      | 2.28ns  | 7.60   |
| 1000-grain weight (GWE)                | 12.68       | 21.08** | 2.90   |
| Productivity (GY)                      | 4.61        | 13.47** | 14.20  |

Note:** significant at P < 0.01;* significant at P < 0.05; ns= non-significant
Analysis of variance and means tested (Table 4) show that the days to 50% flowering (DTF) varied between 77.3 to 87.3 days after sowing (DAS), while the days to harvest (DTH) varied between 110 to 125 DAS. According to BB Padi (2015), the days to harvest or harvest time of rice plants can be grouped as follows: long (more than 151 HSS), moderate (125-150 HSS), early (105-124 HSS), very early (90-104 HSS), and ultra-early (less than 90 HSS). Presented in Table 4, all check varieties and the tested DH lines were categorized as early maturing except for RJ13-DR7-95-1-1 line. Early maturing rice is highly...

Table 3. Plant height and number of reproductive tillers of doubled haploid lines and check varieties

| Genotype   | Plant height (cm) | Number of productive tillers (tiller.hill⁻¹) | Vegetative | Generative |
|------------|-------------------|-----------------------------------------------|------------|------------|
| RJ1 DR7-3-4-1 | 98.7 bcd          | 15.3 c                                        | 127.2      | b          |
| RJ2 DR7-7-6-1 | 96.1 bcde         | 23.8 bc                                       | 109.1      | fg         |
| RJ3 DR7-26-3-1| 76.3 ghij          | 14.0 c                                        | 83.2       | mnpq       |
| RJ4 DR7-31-2-1| 102.2 bc           | 13.4 c                                        | 114.1      | def        |
| RJ5 DR7-35-1-1| 68.0 j            | 21.4 bc                                       | 91.6       | ijk        |
| RJ6 DR7-37-1-1| 84.2 efghi         | 13.7 c                                        | 109.9      | efg        |
| RJ7 DR7-43-1-5| 83.9 efghi         | 19.1 bc                                       | 88.9       | klmno      |
| RJ8 DR7-44-1-2| 90.0 cdef          | 18.8 bc                                       | 94.4       | ijk        |
| RJ9 DR7-67-2-1| 65.4 j            | 16.3 c                                        | 75.6       | q          |
| RJ10 DR7-69-1-1| 67.4 j            | 19.3 bc                                       | 78.2       | pq         |
| RJ11 DR7-69-1-3| 72.7 ij           | 11.6 c                                        | 80.4       | nopq       |
| RJ12 DR7-69-1-4| 86.2 defghi       | 15.8 c                                        | 93.7       | ijk        |
| RJ13 DR7-95-1-1| 76.3 ghij          | 11.6 c                                        | 125.8      | bc         |
| RJ14 DR8-18-1-1| 70.4 j            | 12.4 c                                        | 79.4       | opq        |
| RJ15 DR8-20-1-1| 86.8 defghi       | 16.2 c                                        | 99.0       | hi         |
| RJ16 DR8-23-2-3| 71.4 ij           | 18.0 bc                                       | 83.5       | mnpq       |
| RJ17 DR8-31-1-1| 83.9 efghi        | 17.9 bc                                       | 98.4       | hj         |
| RJ18 DR8-32-2-1| 73.9 hij           | 20.8 bc                                       | 83.0       | mnpq       |
| RJ19 DR8-43-3-1| 74.8 ghij          | 9.0 bc                                         | 94.4       | ijk        |
| RJ20 DR9-4-1-1 | 115.7 a           | 15.0 c                                        | 141.9      | a          |
| RJ21 DR9-11-1-1| 97.6 bcd          | 17.2 c                                        | 108.3      | fg         |
| RJ22 DR9-11-1-2| 92.2 bcde         | 16.6 c                                        | 119.8      | bcd        |
| RJ23 DR9-58-1-1| 77.3 fghij        | 35.2 a                                        | 85.1       | lmnpq      |
| RJ24 DR9-69-2-2| 75.7 ghij          | 17.9 bc                                       | 89.1       | jklmn      |
| RJ25 DR10-14-1-1| 74.3 ghij         | 18.4 bc                                       | 83.6       | mnpq       |
| RJ26 DR10-26-1-1| 75.6 ghij         | 22.3 bc                                       | 86.9       | klmnp      |
| RJ27 DR10-27-3-1| 103.2 b           | 20.4 bc                                       | 125.1      | bc         |
| RJ28 DR10-42-1-1| 69.6 j            | 14.7 c                                        | 78.8       | pq         |
| RJ29 DR11-36-1-1| 94.6 bcde        | 14.7 c                                        | 118.1      | cde        |
| RJ30 DR12-52-2-1| 69.1 j            | 18.2 bc                                       | 75.6       | q          |
| RJ31 Ciherang | 89.9 cdef         | 30.6 ab                                        | 99.3       | hi         |
| RJ32 Inpari 18| 87.3 defg         | 18.0 bc                                        | 96.1       | hij        |
| RJ33 Inpari 40| 87.7 defg         | 19.1 bc                                        | 104.0      | gh         |
| RJ34 Inpari 41| 78.3 fghij        | 19.7 bc                                        | 99.3       | hi         |

Note: The values followed by the same letters within the same column are not significantly different according to DMRT at α 5%.
Table 4. Days to 50% flowering, days to harvest, and panicle length of doubled haploid lines and check varieties

| Genotype         | Days to 50% flowering (DAS) | Days to Harvest (DAS) | Panicle length (cm) |
|------------------|-----------------------------|-----------------------|---------------------|
| RJ1 DR7-3-4-1    | 83.3                        | defg                  | 111.0               |
| RJ2 DR7-7-6-1    | 82.7                        | efgh                  | 112.0               |
| RJ3 DR7-26-3-1   | 83.7                        | cdefg                 | 112.0               |
| RJ4 DR7-31-2-1   | 76.7                        | klmnop                | 110.3               |
| RJ5 DR7-35-1-1   | 85.7                        | abcd                  | 113.3               |
| RJ6 DR7-37-1-1   | 83.7                        | cdefg                 | 112.0               |
| RJ7 DR7-43-1-5   | 75.7                        | lmnpq                 | 115.0               |
| RJ8 DR7-44-1-2   | 75.0                        | mnopq                 | 112.3               |
| RJ9 DR7-67-2-1   | 87.3                        | ab                    | 116.7               |
| RJ10 DR7-69-1-1  | 86.7                        | abcd                  | 115.3               |
| RJ11 DR7-69-1-3  | 87.3                        | ab                    | 118.3               |
| RJ12 DR7-69-1-4  | 82.7                        | efgh                  | 117.0               |
| RJ13 DR7-95-1-1  | 87.0                        | abc                   | 125.0               |
| RJ14 DR8-18-1-1  | 69.3                        | r                     | 111.3               |
| RJ15 DR8-20-1-1  | 79.3                        | hijk                  | 113.3               |
| RJ16 DR8-23-2-3  | 81.0                        | fghi                  | 112.0               |
| RJ17 DR8-31-1-1  | 86.7                        | abcd                  | 110.0               |
| RJ18 DR8-32-2-1  | 76.7                        | klmno                 | 110.7               |
| RJ19 DR8-43-3-1  | 83.0                        | efg                   | 116.0               |
| RJ20 DR9-4-1-1   | 85.3                        | abcde                 | 114.3               |
| RJ21 DR9-9-11-1  | 84.7                        | bcde                  | 120.0               |
| RJ22 DR9-9-11-2  | 80.3                        | ghij                  | 110.0               |
| RJ23 DR9-58-1-1  | 82.67                       | efgh                  | 112.0               |
| RJ24 DR9-69-2-2  | 80.3                        | ghij                  | 117.7               |
| RJ25 DR10-14-1-1 | 73.3                        | oq                    | 110.3               |
| RJ26 DR10-26-1-1 | 73.3                        | opq                   | 110.3               |
| RJ27 DR10-27-3-1 | 80.3                        | ghij                  | 114.3               |
| RJ28 DR10-42-1-1 | 78.3                        | iklm                  | 110.0               |
| RJ29 DR11-36-1-1 | 84.0                        | bcde                  | 114.7               |
| RJ30 DR12-52-2-1 | 78.7                        | ikl                   | 110.0               |
| RJ31 Ciherang    | 88.7                        | a                     | 114.7               |
| RJ32 Inpari 18   | 74.7                        | nopq                  | 111.3               |
| RJ33 Inpari 40   | 77.3                        | jklmn                 | 110.3               |
| RJ34 Inpari 41   | 80.7                        | fgij                  | 110.3               |

Note: The values followed by the same letters within the same column are not significantly different according to DMRT at α 5%. DAS= days after sowing.

Recommended to be planted in rainfed rice fields. This is in accordance with the conditions of rainfed rice fields where the source of water for irrigation is limited from rainfall which is difficult to predict. Early maturity rice is also preferred by farmers at irrigated lowland rice fields because it can increase cropping index from two to three times a year (Fatimah et al., 2014). The panicle length of all tested genotypes varied...
between 19.7 to 26.2 cm (Table 4). RJ6 DR7-37-1-1 has the longest panicle length (26.16 cm), followed by RJ20 DR9-4-1-1 (26.0 cm), RJ21 DR9-11-1-1 (25.6 cm), RJ2 DR7-7-6-1 (24.9 cm) and RJ29 DR11-36-1-1 (24.9 cm). Factors that can affect the length of rice panicles are sudden environmental changes during planting season as well as the amount of nutrients available in the soil (Mulsanti et al., 2014; Zahrah, 2011). Based on the panicle length classification by Rahmah and Aswidinnoor (2013), panicle length can be grouped into short (<20 cm), medium (20-30 cm) and long (> 30 cm) panicle. There is one line, i.e. RJ18 DR8-32-2-1, classified as short panicle, while the other 29 lines and all check varieties classified as medium panicle. RJ6 DR7-37-1-1 and RJ20 DR9-4-1-1 have 9% to 15% longer panicles than all check

### Table 5. Number of grains per panicle in doubled haploid lines and check varieties

| Genotype       | No. filled grains | No. unfilled grains | Total no. grains |
|----------------|-------------------|---------------------|-----------------|
| RJ1 DR7-3-4-1  | 126.6 bcd         | 82.7 abcdefg        | 208.8 bcdef     |
| RJ2 DR7-7-6-1  | 142.9 abcd        | 97.3 abc            | 240.7 abcd      |
| RJ3 DR7-26-3-1 | 163.8 abc         | 59.3 fghi           | 223.4 abcddef   |
| RJ4 DR7-31-2-1 | 130.5 bcd         | 87.7 abcdefg        | 207.8 bcdef     |
| RJ5 DR7-35-1-1 | 156.5 abc         | 60.0 efghi          | 216.4 abcdef    |
| RJ6 DR7-37-1-1 | 151.2 abcd        | 66.8 defghi         | 217.4 abcddef   |
| RJ7 DR7-43-1-5 | 115.2 cd          | 96.7 abc            | 212.0 bcdef     |
| RJ8 DR7-44-1-2 | 189.2 a           | 64.1 defghi         | 254.0 abcd      |
| RJ9 DR7-67-2-1 | 140.4 abcd        | 84.6 abcdefg        | 225.3 abcd      |
| RJ10 DR7-69-1-1| 141.5 abcd        | 87.0 abcdef         | 228.6 abcde     |
| RJ11 DR7-69-1-3| 141.6 abcd        | 89.5 abcde          | 231.0 abcde     |
| RJ12 DR7-69-1-4| 168.1 ab          | 106.3 a             | 274.7 a         |
| RJ13 DR7-95-1-1| 161.7 abc         | 57.6 fghi           | 219.6 abcdef    |
| RJ14 DR8-18-1-1| 116.2 cd          | 46.4 hij            | 162.7 f         |
| RJ15 DR8-20-1-1| 155.1 abc         | 64.8 defghi         | 219.7 abcdef    |
| RJ16 DR8-23-2-3| 146 abcd          | 68.6 cdefghi        | 214.7 abcdef    |
| RJ17 DR8-31-1-1| 102.7 d           | 75.3 bcdefgh        | 177.8 ef        |
| RJ18 DR8-32-2-1| 146.8 abcd        | 62.6 efghi          | 209.2 bcdef     |
| RJ19 DR8-43-3-1| 142.1 abcd        | 56.4 ghi            | 199.0 cdef      |
| RJ20 DR9-4-1-1 | 125.9 bcd         | 89.1 abcde          | 215.4 abcdef    |
| RJ21 DR9-11-1-1| 184.6 a           | 62.7 efghi          | 247.5 abcd      |
| RJ22 DR9-11-1-2| 150.3 abcd        | 81.8 abcdefg        | 231.4 abcde     |
| RJ23 DR9-58-1-1| 116.2 cd          | 89.5 abcde          | 205.6 bcdef     |
| RJ24 DR9-69-2-2| 157.5 abc         | 98.1 ab             | 256.2 abcd      |
| RJ25 DR10-14-1-1| 182.5 a           | 83.1 abcdefg        | 266.3 ab        |
| RJ26 DR10-26-1-1| 163.3 abc         | 93.3 abcde          | 257.0 abcd      |
| RJ27 DR10-27-3-1| 180.2 a           | 81.1 abcdefg        | 261.5 abc       |
| RJ28 DR10-42-1-1| 145.6 abcd        | 72.1 bcdefghi       | 217.6 abcdef    |
| RJ29 DR11-36-1-1| 155.6 abc         | 87.2 abcdef         | 242.5 abcde     |
| RJ30 DR12-52-2-1| 167.7 ab          | 43.8 ij             | 211.5 bcdef     |
| RJ31 Cihering | 181 a             | 55.8 ghi            | 236.9 abcde     |
| RJ32 Inpari 18 | 174.6 ab          | 63.1 efghi          | 237.6 abcde     |
| RJ33 Inpari 40 | 190 a             | 60.4 efghi          | 250.3 abcde     |
| RJ34 Inpari 41 | 169 ab            | 27.8 j              | 196.2 def       |

Note: Values followed by the same letters within the same column are not significantly different according to DMRT at α 5%.
varieties. Despite the grain size, the total number of grains per panicle depends on the panicle length. In general, the total number of grains tends to increase in a longer panicle (Nazirah and Damanik, 2015).

The number of filled grains per panicle is one of the selection criteria to obtain lines with high yields. The results of the analysis showed the average number of filled grains per panicle of DH lines ranged from 102.7-189.2 grains, while the number of unfilled grain ranged from 27.8 - 106.3 grains (Table 5). In this experiment, twenty-three DH lines has non-significantly different number of filled grains compared to the four check varieties. The number of filled and unfilled grains is influenced by genetic and environmental factors. Spikelet fertility and seed yield per panicle were severely reduced by extreme temperature in the 14 days period before anthesis (Eixarch and Ellis, 2015). Too low temperature affected spikelet fertility (Zeng et al., 2017), while too high temperature will inhibit the development of pollen grains in the anther resulted in sterile spikelets and unfilled grains, thus decrease the number of filled grains (Khamid, 2016). Other factors that influence the amount of filled and unfilled grains include the level of pests and diseases attacks during planting season.

The number of grains per panicle ranged between 162.7 - 274.7 grains (Table 5). Among the check variety, RJ34 Inpari 41 has the least number of grains per panicle, 196.2 grains. There are 27 lines that have grains number per panicle not significantly different from check variety RJ33 Inpari 40. Abdullah et al. (2008) stated that the high number of grains per panicle will extend maturation phase, thus it will increase the number of empty grains due to imbalance of source and sink, especially in new plant type (NPT) of rice.

The results of the analysis of the percentage of filled grain are presented in Table 6. Check variety RJ34 Inpari 41 has the highest average percentage of filled grain of 86.9%. There are 12 DH lines that have percentage of filled grain not significantly different from RJ34 Inpari 41. The grain yield is strongly influenced by several factors, namely genetic and environmental factors. Determination of the variety used, the choice of growing environment, the amount of light intensity, and the presence of pest and disease determine how much yield to be harvested (Wahyuni et al., 2013).

Seed index or 1,000-grain weight ranges from 22.5-31.0 g (Table 6). The lowest 1,000-grain weight was found in RJ25 DR10-14-1-1 line which was not significantly different from the RJ26 line DR10-26-1-1, and check variety RJ33 Inpari 40. The RJ11 DR7-69-1-3 had the highest 1,000-grain weight, not different from RJ10 DR7-69-1-1, RJ9 DR7-67-2-1, RJ5 DR7-35-1-1 and check variety RJ32 Inpari 18. Juahir et al. (2013) classified 1,000-grain weights as light (<25 g), moderate (25-30 g), and heavy (>30 g). Four DH lines were classified as light, 24 DH lines as moderate, and two DH lines as heavy in 1000-grain weight. The 1,000-grain weights of check varieties RJ33 Inpari 40 classified as light, while RJ31 Cihetang, RJ32 Inpari18, and RJ34 Inpari 41 were classified as moderate. Factors influencing the weight of 1,000-grain include the availability of water in the pollination and grain filling phases. Sujiahah and Jamil (2016) stated that the lack of water will reduce the weight of 1,000 grains.

Productivity of DH lines ranges from 2.10 to 7.12 tons.ha⁻¹ (Table 6). RJ7 DR7-43-1-5 has the lowest productivity while the check variety RJ31 Cihetang has the highest productivity. There are two DH lines, i.e., RJ19 DR8-43-3-1 (7.12 tons.ha⁻¹) and RJ25 DR10-14-1-1 (6.45 tons.ha⁻¹) which has the same productivity as the four check varieties. Mahmud and Purnomo (2014) stated that productivity is closely related to the yield components such as the number of productive tillers per hill, the number of grains per panicle, the percentage of filled grains, and the 1,000-grain weight.

Correlation Analysis for Determining Good Agronomic Performance

The relationship between agronomic traits and yield is known from the correlation analysis values presented in Table 7. The generative plant height correlates positively and very significantly with the vegetative plant height (r=0.85, P<0.01). The high plant height at reproductive stage is a result from high plant height at vegetative stage, which is not desirable (Dewi et al., 2015). The heading character correlates positively and very significantly with days to harvest (r=0.52, P<0.01). Faozi et al. (2010) stated that days to harvest was determined by the speed of heading, because in general rice plants have different duration of vegetative period, while the grain filling period is relatively similar.

The number of grain was positively and very significantly correlated to the character of the number of filled grains per panicle (r=0.71, P<0.01). The results of this analysis are in line with the results of Kartina et al. (2016) which stated that an increase in the total number of grains per panicle is accompanied by an increase in the overall number of filled grain. Increasing the number of filled grains per panicle will be followed by the addition of grain yield per hill. Moreover, grain yield per hectar or productivity positively correlates with the number of vegetative
The large correlation coefficient shows a close relationship between the characters observed (Prabowo et al., 2014). In this experiment a close relationship appeared between vegetative plant height and generative plant height, days to 50% flowering and days to harvest, number of unfilled tillers, the number of filled grains per panicle, and the percentage of filled grain, but negatively correlated with the number of unfilled grains and the percentage of unfilled grains. The large correlation coefficient shows a close relationship between the characters observed

| Genotype       | Percentage of filled grain (%) | 1000-grain weight (g) | Productivity (tons.ha⁻¹) |
|----------------|--------------------------------|-----------------------|-------------------------|
| RJ1 DR7-3-4-1  | 60.7 bc                        | 26.3 hijkm            | 3.26 ijk                |
| RJ2 DR7-7-6-1  | 58.9 c                         | 28.9 bcd              | 4.10 efgih              |
| RJ3 DR7-26-3-1 | 72.9 ab                        | 25.0 mnop             | 5.25 bcde               |
| RJ4 DR7-31-2-1 | 62.0 bc                        | 28.7 bcd              | 4.60 cdefgh             |
| RJ5 DR7-35-1-1 | 73.0 ab                        | 29.6 abc              | 5.12 cdefg              |
| RJ6 DR7-37-1-1 | 69.4 ab                        | 27.1 fghijk           | 3.77 hij                |
| RJ7 DR7-43-1-5 | 54.0 c                         | 26.5 hijkm            | 2.10 k                  |
| RJ8 DR7-44-1-2 | 74.3 ab                        | 26.2 iklmn            | 4.50 cdefghi            |
| RJ9 DR7-67-2-1 | 62.2 bc                        | 29.6 abc              | 5.17 cdef               |
| RJ10 DR7-69-1-1| 62.2 bc                        | 30.5 a                | 5.25 bcde               |
| RJ11 DR7-69-1-3| 60.8 bc                        | 31.0 a                | 3.99 efgih              |
| RJ12 DR7-69-1-4| 61.3 bc                        | 24.8 nop              | 3.13 jk                 |
| RJ13 DR7-95-1-1| 73.7 ab                        | 26.5 hijkm            | 4.70 cdefgh             |
| RJ14 DR8-18-1-1| 71.3 ab                        | 27.2 efgihk           | 2.40 k                  |
| RJ15 DR8-20-1-1| 70.4 ab                        | 27.6 defghi           | 5.05 cdefgh             |
| RJ16 DR8-23-2-3| 68.0 bc                        | 27.1 fghijk           | 4.18 defghij            |
| RJ17 DR8-31-1-1| 57.9 c                         | 26.3 hijkm            | 4.08 efgih              |
| RJ18 DR8-32-2-1| 70.0 abc                       | 28.1 defg             | 4.05 efgij              |
| RJ19 DR8-43-3-1| 70.9 ab                        | 28.9 bcd              | 7.12 a                  |
| RJ20 DR9-4-1-1 | 58.0 bc                        | 26.1 jklmno           | 3.83 ghij               |
| RJ21 DR9-9-11-1| 74.4 ab                        | 27.8 defgh            | 4.62 cdefgh             |
| RJ22 DR9-9-11-2| 64.7 bc                        | 25.1 mnop             | 3.74 hj                 |
| RJ23 DR9-58-1-1| 56.6 bc                        | 27.3 efgih             | 3.18 ijk                |
| RJ24 DR9-69-2-2| 61.0 bc                        | 25.4 lmo              | 5.29 bcde               |
| RJ25 DR10-14-1-1| 68.3 bc                       | 22.5 q                | 6.45 ab                 |
| RJ26 DR10-26-1-1| 63.0 bc                       | 22.8 q                | 5.62 bc                 |
| RJ27 DR10-27-3-1| 69.0 ab                       | 28.4 cdef             | 5.55 bcd                |
| RJ28 DR10-42-1-1| 67.3 bc                       | 24.7 op               | 4.75 cdefgh             |
| RJ29 DR11-36-1-1| 63.1 bc                       | 28.0 defg             | 3.89 fghij              |
| RJ30 DR12-52-2-1| 79.2 ab                       | 25.8 klmno            | 4.40 cdefghij           |

Note: The values followed by the same letters within the same column are not significantly different according to DMRT at α 5%.

Table 6. Percentage of filled grain, 1000-grain weight and productivity of doubled haploid lines and check varieties

(Robowo et al., 2014).
Table 7. Pearson correlation analysis between traits in doubled haploid rice lines

|       | VPH  | GPH  | NVT  | NPT  | DTF  | DTH  | PL   | NFG  | NUG  | NTG  | %NFG | %NUG  | GWE  | GY   |
|-------|------|------|------|------|------|------|------|------|------|------|------|-------|------|------|
| VPH   | 1    |      |      |      |      |      |      |      |      |      |      |       |      |      |
| GPH   | -0.395** | 1    |      |      |      |      |      |      |      |      |      |       |      |      |
| NVT   | -0.063 | -0.215 | 0.44** | 1    |      |      |      |      |      |      |      |       |      |      |
| NPT   | 0.062  | 0.246 | 0.114 | 0.1  | 1    |      |      |      |      |      |      |       |      |      |
| DTF   | -0.029 | 0.162 | -0.043 | -0.16 | 0.522** | 1    |      |      |      |      |      |       |      |      |
| DTH   | 0.562** | 0.551** | -0.417* | -0.142 | 0.43* | 0.288 | 1    |      |      |      |      |       |      |      |
| PL    | 0.092  | 0.043 | 0.236 | 0.033 | -0.133 | 0.095 | 0.013 | 1    |      |      |      |       |      |      |
| NFG   | 0.255  | 0.118 | 0.017 | 0.077 | 0.102 | 0.164 | 0.235 | -0.285 | 1    |      |      |       |      |      |
| NUG   | 0.273  | 0.127 | 0.228 | 0.087 | -0.047 | 0.208 | 0.186 | 0.706** | 0.477** | 1    |      |       |      |      |
| NTG   | -0.188 | -0.09  | 0.093 | -0.065 | -0.153 | -0.084 | -0.192 | 0.666** | -0.896** | -0.051 | 1    |       |      |      |
| %NFG  | 0.184  | 0.09   | -0.093 | 0.065 | 0.153 | 0.084 | 0.192 | -0.666** | 0.896** | 0.051 | -1** | 1      |      |      |
| %NUG  | -0.05  | -0.026 | 0.041 | 0.088 | 0.397* | 0.301 | 0.256 | -0.23  | -0.06 | -0.255 | -0.047 | 0.047 | 1    |      |
| GWE   | -0.082 | -0.072 | 0.485** | 0.242 | 0.058 | -0.028 | -0.119 | 0.623** | -0.386* | 0.286 | 0.574** | -0.574** | 0.003 | 1    |
| GY    |       |       |       |       |       |       |       |       |       |       |       |       |       |      |

Note: ** Significant at $P < 0.01$, * significant at $P < 0.05$. VPH= vegetative plant height; GPH= generative plant height; NVT= number of vegetative tiller; NPT= number of productive tiller; DTF= days to 50% flowering; DTH= days to harvest; PL= panicle length; NFG= number of filled grains; NUG= number of unfilled grains; NTG= number of grains per panicle; %NFG= percentage of filled grain; %NUG= percentage of unfilled grain; GWE= 1000-grain weight; GY= productivity.

Selection Index to Obtain Superior Lines

Table 8 shows that the check variety RJ34 Ciherang has the highest index value of 15.49 while the RJ7 DR7-43-1-5 line has the lowest index value of -14.74. Selection of doubled-haploid rice lines with superior agronomic character and high yield can be done through indirect selection using characters correlated to productivity (Aryana, 2009). The selection method used is weighted selection index which involves productivity (GY) and selected variables that have a significant effect to grain yield from analysis correlation, i.e., number of filled grains (NFG) and percentage of filled grain (%FG) and characters suitable for rainfed lowland paddy field, i.e. number of productive tiller (NPT) and days to harvest (DH). Before establishing the selection index model, the selected traits were given a weight of 1 to 5 to maximize the model as suggested by Sabouri et al. (2008). Therefore, the model of selection index (I) was formulated as follow:

\[ I = (5*GY) + (2*NPT) + (2* NFG) + (1*%FG) – (1*DH). \]

The high weighting of the character of productivity and agronomic characters related to productivity in that formulation was based on the economic value (Ramos et al., 2014; Gazal et al., 2017). In addition, positive and negative signs indicated the direction of selection, i.e. increased number of filled grain and decreased days to harvest, respectively.

Based on the positive index value and good agronomic performance including phenotypic acceptability, i.e., medium number of productive tiller, early maturing and productivity more than 4.40 t/ha, 12 DH lines can be selected as materials for further yield trials in the rainfed lowland rice fields (Table 8). They are RJ3 DR7-26-3-1, RJ5 DR7-35-1-1, RJ8 DR7-44-1-2, RJ13 DR7-95-1-1, RJ15 DR8-20-1-1, RJ19 DR8-43-3-1, RJ21 DR9-11-1-1, RJ25 DR10-14-1-1, RJ26 DR10-26-1-1, RJ27 DR10-27-3-1, RJ28 DR10-42-1-1, RJ30 DR12-52-2-1. All selected DH lines had good and acceptable agronomic characters similar to the released varieties used as checks (Table 3, 4, 5, and 6). In addition, in Indonesia rice varieties under cultivation in rainfed lowlands were low yielding ranged from 2.00 to 3.50 tons.ha$^{-1}$ as reported by Kasno et al. (2016). Thus, those twelve selected DH lines are potential to be tested in further yield trials program.

Conclusion

The DH lines tested in this study have variability in agronomic traits. Number of tillers at vegetative stage, number of grains and filled grain per panicle, and percentage of filled grain positively and significantly correlated to grain yield or productivity, while plant height at vegetative and generative stages, days to harvest, panicle length, and number of unfilled grains...
| Rank | Genotype     | Agronomic characters* | I** |
|------|--------------|-----------------------|-----|
|      |              | NPT       | NFG | % NFG | DTH   | GY |     |
| 1    | RJ31 Ciherang| 30.6      | 181.0 | 75.5 | 114.7 | 7.00 | 15.49 |
| 2    | RJ34 Inpari 41| 19.7      | 169.0 | 86.9 | 110.3 | 7.24 | 12.99 |
| 3    | RJ33 Inpari 40| 19.1     | 190.0 | 76.2 | 110.3 | 6.92 | 11.58 |
| 4    | RJ32 Inpari 18| 18.0      | 174.6 | 73.8 | 111.3 | 6.88 | 9.96  |
| 5    | RJ25 DR10-14-1-1| 18.4     | 182.5 | 68.3 | 110.3 | 6.45 | 8.27  |
| 6    | RJ19 DR8-43-3-1| 19.0      | 142.1 | 70.9 | 116.0 | 7.12 | 7.26  |
| 7    | RJ3 DR7-26-3-1| 14.0      | 163.8 | 72.9 | 112.0 | 5.25 | 3.93  |
| 8    | RJ27 DR10-27-3-1| 20.4     | 180.2 | 69.0 | 114.3 | 5.55 | 3.49  |
| 9    | RJ16 DR8-42-1-1| 22.3      | 163.3 | 63.0 | 110.3 | 5.62 | 3.38  |
| 10   | RJ8 DR7-44-1-2| 18.8      | 189.2 | 74.3 | 112.3 | 4.50 | 2.03  |
| 11   | RJ5 DR7-35-1-1| 21.4      | 156.5 | 73.0 | 113.3 | 5.12 | 1.95  |
| 12   | RJ30 DR12-52-2-1| 18.2     | 167.7 | 79.2 | 110.0 | 4.40 | 1.70  |
| 13   | RJ15 DR8-20-1-1| 16.2      | 155.1 | 70.4 | 113.3 | 5.05 | 1.26  |
| 14   | RJ28 DR10-26-1-1| 14.7     | 145.6 | 67.3 | 110.0 | 4.75 | 0.69  |
| 15   | RJ13 DR7-95-1-1| 11.6      | 161.7 | 73.7 | 125.0 | 4.70 | 0.37  |
| 16   | RJ21 DR9-11-1-1| 17.2      | 184.6 | 74.4 | 120.0 | 4.62 | 0.00  |
| 17   | RJ24 DR9-69-2-2| 17.9      | 157.5 | 61.0 | 117.7 | 5.29 | -0.49 |
| 18   | RJ10 DR7-68-1-1| 19.3      | 141.5 | 62.2 | 115.3 | 5.25 | -0.74 |
| 19   | RJ9 DR7-67-2-1| 16.3      | 140.4 | 62.2 | 116.7 | 5.17 | -1.22 |
| 20   | RJ4 DR7-31-2-1| 13.4      | 130.5 | 62.0 | 110.3 | 4.60 | -1.63 |
| 21   | RJ2 DR7-7-6-1| 23.8      | 142.9 | 58.9 | 112.0 | 4.10 | -2.20 |
| 22   | RJ18 DR8-32-2-1| 20.8     | 146.8 | 70.0 | 110.7 | 4.05 | -2.34 |
| 23   | RJ16 DR8-23-2-3| 18.0      | 146.0 | 68.0 | 112.0 | 4.18 | -2.56 |
| 24   | RJ6 DR7-37-1-1| 13.7      | 151.2 | 69.4 | 112.0 | 3.77 | -2.75 |
| 25   | RJ22 DR9-11-1-2| 16.6      | 150.3 | 64.7 | 110.0 | 3.74 | -3.69 |
| 26   | RJ29 DR11-36-1-1| 14.7   | 155.6 | 63.1 | 114.7 | 3.89 | -3.94 |
| 27   | RJ23 DR9-58-1| 35.2      | 116.2 | 56.6 | 112.0 | 3.18 | -4.66 |
| 28   | RJ17 DR8-31-1-1| 17.9      | 102.7 | 57.9 | 110.0 | 4.08 | -6.24 |
| 29   | RJ11 DR7-69-1-3| 17.1      | 141.6 | 60.8 | 118.3 | 3.99 | -6.47 |
| 30   | RJ20 DR9-4-1-1| 15.0      | 125.9 | 58.0 | 114.3 | 3.83 | -6.96 |
| 31   | RJ12 DR7-69-1-4| 15.8      | 168.1 | 61.3 | 117.0 | 3.13 | -7.10 |
| 32   | RJ1 DR7-3-4-1| 15.3      | 126.6 | 60.7 | 111.0 | 3.26 | -7.58 |
| 33   | RJ14 DR8-18-1-1| 12.4      | 116.2 | 71.3 | 111.3 | 2.40 | -9.27 |
| 34   | RJ7 DR7-43-1-5| 19.1      | 115.2 | 54.0 | 115.0 | 2.10 | -14.74 |

Note: *NPT=number of productive tiller (tiller per hill); NFG= Number of filled grains (grain panicle-1); % NFG= percentage of filled grains (%); DTH= days to harvest (DAS);
*I: index value based on standardized selection index.
negatively correlated to grain yield. There were twelve DH lines that have potential to be tested further in yield trials program for rainfed lowland paddy field. The selected DH lines have good agronomic characters, especially in number of productive tiller, early maturing, and productivity of more than 4.40 tons.ha⁻¹.

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**References**

Abdullah, B., Tjokrowidjojo, S., and Sularjo (2008). Perkembangan dan prospek perakitan padi tipe baru di Indonesia. *Jurnal Litbang Pertanian* 27, 1-9.

Akbar, M.R, Purwoko, B.S., Dewi, I.S., Suwarno, W.B., and Sugiyanta (2018). Agronomic and drought tolerance evaluation of doubled haploid rice breeding lines derived from anther culture. *SABRAO Journal of Breeding and Genetics* 50, 115-128.

Aryana, I.G.P.M. (2009). Korelasi fenotipik, genotipik dan sidik lintas serta implikasinya pada seleksi padi beras merah. *Crop Agro* 2, 14-20.

Dewi, I.S. and Purwoko, B.S. (2001). Kultur antera untuk mendukung program pemuliaan tanaman padi. *Bulletin Agronomi* 29, 59-63.

Dewi, I.S. and Purwoko, B.S. (2011). Kultur in-vitro untuk pembentukan tanaman haploid androgenik” pp. 107-158 In “Bioteknologi untuk Pemuliaan Tanaman” (G.A Wattimena, Nurhayati, A. Mattjik, N.M.A. Wiendi, A. Purwito, D. Efendi, B.S. Purwoko, N. Khumaida eds.). IPB Press.

Dewi, I.S., Lestari, E.G., Chaerani, and Yunita, R. (2015). Penampilan galur harapan mutan dihaploid padi tipe baru di Sulawesi Selatan. *Jurnal Agronomi Indonesia* 43, 89-98.

Dewi, I.S., Syafii, M., Purwoko, B.S., and Suwarno, W.B. (2017). Efficient indica rice anther culture derived from three way-crosses. *SABRAO Journal of Breeding and Genetics* 49, 336-345.

Donggulo, C.V., Lapanjiang, I.M., Made, U. (2017). Pertumbuhan dan hasil tanaman padi (Oryza sativa L.) pada berbagai pola jajar legowo dan jarak tanam. *Jurnal Agroland* 24, 27-35.

Eixarch, M.M. and Ellis, R.H. (2015). Temporal sensitivities of rice seed development from spikelet fertility to viable mature seed to extreme-temperature. *Crop Science* 55, 354-364. doi: 10.2135/cropsci2014.01.0042.

Falconer, D.S. and Mackay T.F.C. (1996). “Introduction to Quantitative Genetics”. 4th ed., Malaysia, Longman Essex. 356p.

Fatimah, Prasetyono, J., Dadang, A., and Tasliah. (2014). Improvement of early maturity in rice variety by marker asissted backcross breeding of Hd2 gene. *Indonesian Journal of Agricultural Science* 15, 55-64.

Fukushima, A. (2019) Varietal differences in tiller and panicle development determining the total number of spikelets per unit area in rice. *Plant Production Science* 22,192-201, DOI: 10.1080/1343943X.2018.1562308.
Gazal, A., Nehvi, F.A., Lone, A.A., Dar, Z.A., and Wani, M.A. (2017). Smith hazel selection index for the improvement of maize inbred lines under water stress conditions. *International Journal of Pure Applied Bioscience* 5, 72-81.

Gomez, K.A., Gomez, A.A. (1984). “Statistical Procedures for Agricultural Research”. 2nd ed., John Willey and Sons, NY, USA. 335 p.

[IRRI] International Rice Research Institute. (2013). “Standard Evaluation System for Rice”. IRRI. Los Banos. PH.

Juahirah, Masniawati, A., Tambaru, E., and Sajak, A. (2013). Karakterisasi malai padi lokal asal Kabupaten Tanah Toraja Utara Sulawesi Selatan. *Jurnal Ilmiah Ilmu Pengetahuan Alam Sainsmat* 2, 22-31.

Kartina, N., Purwoko, B.S., Dewi, I.S., Wirnas, D., and Sugiyanta. (2019). Genotype by environment interaction and yield stability analysis of doubled haploid lines of upland rice. *SABRAO Journal of Breeding and Genetics* 51, 191-204.

Kasno, A., Rostaman, T., and Setyorini, D. (2016). Peningkatan produktivitas lahan sawah tadah hujan dengan pemupukan hara N, P, dan K dan penggunaan padi varietas unggul. *Jurnal Tanah dan Iklim* 40, 147-157.

Khamid, M.B.R. (2016). Mekanisme tanaman padi (*Oryza Sativa* L.) dalam menghadapi cekaman suhu tinggi pada stadia generatif. *Jurnal Agrotek Indonesia* 1, 129-139.

Mahmud, Y. and Purnomo, S.S. (2014). Keragaman agronomis beberapa varietas unggul baru tanaman padi (*Oryza sativa* L.) pada model pengelolaan tanaman terpadu. *Jurnal Ilmiah Solusi* 1, 1-10.

Munarso, Y.P. (2010). Sifat kegenjahan dan toleran kekerasan beberapa galur padi sebagai calon tetua. *Agrovigor* 3, 125-130.

Mulsanti, I.W., Wahyuni, S., and Sembiring, H. (2014). Hasil padi dari empat kelas benih berbeda. *Jurnal Penelitian Pertanian Tanaman Pangan* 33, 169-176.

Mulusew, F., Edossa, F., Tadele, T., and Teshome, L. (2009). Parametric stability analyses in field pea (*Pisum sativum* L.) under south-eastern Ethiopian conditions. *World Journal of Agricultural Science* 5, 146-151.

Nazirah, L., Sengli, B., and Damanik, J. (2015). Pertumbuhan dan hasil tiga varietas padi gogo pada perlakuan pemupukan. *Jurnal Floratek* 10, 54-60.

Pabendon, M.B. and Takdir M.A. (2000). Penampilan fenotipik dan hasil beberapa karakter penting 10 jagung hibrida harapan berumur genjah di Maros, Sulawesi Selatan. *Zuriat* 11, 27-31.

Prabowo, H., Djoar, D.W., and Pardjanto. (2014). Korelasi sifat-sifat agronomi dengan hasil dan kandungan antosianin padi beras merah. *Agrosains* 16, 49-54.

Rahmah, R. and Aswidinnoor, H. (2013). Uji daya hasil lanjutan 30 galur padi lipe baru generasi F6 hasil dari 7 kombinasi persilangan. *Bulletin Agrohorti* 1, 1-8.

Rachmawati, D. and Retnaningrum, E. (2013). Pengaruh tinggi dan lamanya genangan terhadap pertumbuhan padi kultivar Stinar dan dimanika populasi rhizobakteri pemfiksasi nitrogen non simbiosis. *Bionatura-Jurnal Ilmu-Ilmu Hayati dan Fisik* 15, 117-125.

Rahayu, A.Y. and Harjoso, T. (2010). Karakter agronomi dan fisiologi padi gogo yang ditanam pada media tanah bersekat pada kondisi air dibawah kapasitas lapang. *Akta Agrosia* 13, 40-49.

Ramos, H.C.C., Pereira, M.G., Viana, A.P., da Luz, L.N., Cardoso, D.L., and Ferrequeutti, G.A. (2014). Combined selection in backcross population of papaya (*Carica papaya* L.) by the mixed model methodology. *American Journal of Plant Science* 5, 2973-2983.

Sabouri H, Rabiei, B., and Fazlalipour, M. (2008). Use of selection indices based on multivariate analysis for improving grain yield in rice. *Rice Science* 15, 303–310.

Sitaresmi, T., Nafisah, Gunarsih, C., and Daradjat, A.A. (2012). Analisis stabilitas hasil gabah galur-galur padi melalui pendekatan parametrik dan non parametrik. *Jurnal Penelitian Pertanian* 31, 79-86.

Sujinah and Jamil, A. (2016). Mekanisme respon tanaman padi terhadap cekaman kekerasan dan varietas toleran. *Iptek Tanaman Pangan* 11, 1-8.
Syafii, M., Purwoko, B.S., Dewi, I.S., and Suwarno, W.B. (2018). Karakter agronomi galur padi dihaploid asal kultur antera hasil persilangan three way cross. Jurnal Agronomi Indonesia 46, 9-16.

Wahyuni, S., Mulsanti, I.W., and Satoto. (2013). Produktivitas varietas padi dari kelas benih berbeda. Iptek Tanaman Pangan 8, 62-71.

Wang, Y., Lu, J., Ren, T., Hussain, S., Guo, C., Wang, S., Cong, R., and Li X. (2017). Effects of nitrogen and tiller type on grain yield and physiological responses in rice. AoB PLANTS 9 plx012; doi:10.1093/aobpla/plx012.

Zahrah, S. (2011). Aplikasi pupuk bokashi dan NPK organik pada tanah ultisol untuk tanaman padi sawah dengan system SRI (System of Rice Intensification). Jurnal Lingkungan 5, 114-129.

Zeng, Y., Zhang, Y., Xiang, J., Uphoff, N.T., Pan, X., and Zhu, D. (2017). Effect of low temperature stress on spikelet-related parameters during anthesis in Indica - Japonica hybrid rice. Frontier in Plant Science 8,1350. doi: 10.3389/fpls.2017.01350