Promising upland rice lines as new shading tolerant varieties with good grain quality

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Abstract. The utilization of coconut plantation land to increase rice planting area is a potential effort to maintain food sustainability in Indonesia. The development of shading tolerant rice varieties has been undertaken through plant breeding programs. Preliminary yield trial of upland rice genotypes under coconut plantation with 50% light intensity have been carried out in the village of Cilincing, Tegalbulued District, Sukabumi in the WS 2017. The genotype consists of 36 rice lines 4 check varieties, i.e Inpago 8, Limboto, Situpatenggang, and Jatiluhur. The result showed that the height of the lines ranged from 70.8 cm - 111.1 cm and the number of productive tillers were between 3 - 11.9 tillers. The line B15341-1B-TB-29 showed the earliest flowering time of 83 days after sowing (DAS). The panicle length of rice genotypes ranged from 29.4 cm - 21.8 cm and the average weight of 1000 grains of the line was 25.7 g. The ranges of filled grain per panicle of the lines were 47-157 grains. B14908C-MR-1-25-1-3 had the highest amount of the number of filled grain per panicle. Amylose levels of those genotypes were in the range of 17-22% and the rice texture was sticky to medium. The shape and size of the rice were long to medium. There were six promising rice, namely B14981B-TGB-4, B15344B-TB-30, B15175C-TGB-39, B15209B-MR-17-1, B14908C-MR-1-25-1-3, and B14192E-MR-33 that have the potential to be released as new shade-tolerant varieties.

1. Introduction
The agricultural land conversion into industrial facilities and settlements continues to increase which significantly reduces the agricultural land availability and threatens food supply [6]. It is necessary to extend the rice planting area by using marginal land as dry land in the low or highland. The government’s effort to fulfill the food needs utilize suboptimal land maximally because the majority of land in Indonesia was suboptimal such as dry land 148 million Ha (76.5%) from total land in Indonesia [4][9]. The dry land which was suitable for agricultural cultivation was about 76.22 million Ha (52%) [1].

The development of upland rice is directed to the plantation area where upland rice is planted among annual crops such as coconut, oil palm, teak, and rubber. Plantation areas in Indonesia have enormous potential for the extensification of rice production [2]. The area of land that has the potential to overlap upland rice on the land is estimated to reach 2 million ha per year [11]. In such conditions, rice plants often experience a lack of light so production is low. To overcome the stress, rice varieties that are tolerant to shade are required [5].

This research aimed to evaluate the appearance and yield of advanced generation strains of upland rice tolerant to shade and have good quality rice. Lines with high yields and good quality rice have the potential to be released as new shade-tolerant superior varieties.
2. Material and method

2.1. Time and place
The experiment was conducted in Sukabumi, West Java in MT1 2018. The experiment was carried out under coconut plantation with 50% sunlight intensity.

2.2. Materials
A total of 30 lines and check varieties i.e Inpago 8, Limboto, Situpatenggang, and Jatiluhur were used as the experimental material.

2.3. Experiment design
Design of this experiment was randomize complete block design with four replication. The plot size was 2 m x 5 m, spacing was 30 cm x 15 cm. Planting was done with the number of seeds 2-3 grains per hole. Fertilization used were 300 kg/ha NPK + 100 kg/ha Urea. Pests and diseases were controlled optimally.

2.4. Observation
The variables observed were plant height, number of productive tillers, age of flowering plants (50%), age can be harvested (80% yellowing rice), amount of filled grain and empty per panicle, 1000 grain weight (14% moisture content), yield (14% moisture content) and grain quality.

2.5. Data analysis
Data were analyzed using analysis of variance. The difference in average between lines will be tested with the Least Significant Difference (LSD) at the real difference level of 5%.

3. Result

3.1. Field performance
The performance and recapitulation of agronomic components of plant height, number of productive tillers, flowering age, harvest age, and yield of tested lines were shown in Figure 1 and Table 1. The height of the lines ranged from 70.8 cm - 111.1 cm. According to [7] the shade level have significant effect on the plant height and leaves number. Plant height of the check varieties were decline when compared to the characters in their description in [10]. The number of productive tillers were between 3 - 11.9 tillers. Jatiluhur was a check with the highest tillers 6.7 than another check. The earliest flowering age was B15341-1B-TB-29 with an age of 83 DAS. Inpago 8 was the earliest check variety with 84 DAS and the deepest was Limboto with 91.3 DAS. The average flowering age of the lines was between 83 - 99 DAS.

Figure 1. Yield experiment of upland rice lines at Tegalbuleud, Sukabumi WS 2017

The lengths of panicles of the lines were in the range of 29.4 cm - 21.8 cm where the lines with the longest panicle were B15053F-PWR-8 (Table 2). There were 7 lines with not significantly different panicle length from the best check varieties Limboto (26.7 cm), namely B15231-MR-10-1, B15344B-TB-30, B14958-MR-11-25-4-1, B14908C-MR-1-25-1-3, B14192E-MR-33, and B11908F-TB-1-1.
Table 1. Agronomic characters of upland rice lines, Tegalbuleud, Sukabumi, WS 2017

| No | Line                  | Plant height | No. of productive tiller | Day to flowering | Day to harvest |
|----|----------------------|--------------|--------------------------|------------------|----------------|
| 1  | B14168E-MR-2         | 73.9         | 4.7                      | 96.3             | 123            |
| 2  | B11908F-TB-1-1       | 77.2         | 3.0                      | 99.0             | 126            |
| 3  | B12825E-TB-2-4       | 90.7         | 4.0                      | 96.3             | 118            |
| 4  | B11908D-MR-2-2-2     | 71.9         | 4.2                      | 91.3             | 118            |
| 5  | B11423G-MR-1-7       | 90.6         | 4.7                      | 96.0             | 123            |
| 6  | B14129U-MR-5         | 89.6         | 3.8                      | 98.0             | 125            |
| 7  | B14129E-MR-13        | 103.4        | 4.4                      | 88.3             | 115            |
| 8  | B15053F-PWR-8        | 70.8         | 3.4                      | 97.3             | 124            |
| 9  | B11957-RS*-2-3-2-18-2-SI-2-MR-2-PN-3-3 | 81.7         | 3.8                      | 99.0             | 126            |
| 10 | B15175C-TGB-13       | 82.8         | 4.6                      | 96.0             | 123            |
| 11 | B15175C-TGB-16       | 79.4         | 5.0                      | 94.7             | 122            |
| 12 | B15175C-TGB-23       | 75.3         | 6.3                      | 86.7             | 115            |
| 13 | B14957-MR-2-3-2      | 84.0         | 5.4                      | 86.3             | 113            |
| 14 | B14958-MR-11-25-4-1  | 95.7         | 8.8                      | 85.7             | 113            |
| 15 | B15114C-TB-22        | 110.8        | 7.4                      | 84.3             | 111            |
| 16 | B15341-1B-TB-2       | 95.8         | 8.4                      | 87.0             | 114            |
| 17 | B15341-1B-TB-29      | 100.4        | 8.3                      | 83.0             | 110            |
| 18 | B14981B-TGB-4        | 111.1        | 11.9                     | 84.3             | 111            |
| 19 | B15344B-TB-30        | 108.2        | 8.0                      | 87.0             | 114            |
| 20 | B15344B-TB-34        | 101.0        | 6.2                      | 91.7             | 118            |
| 21 | B14168E-MR-10-1      | 85.3         | 7.0                      | 93.0             | 120            |
| 22 | B15175C-TGB-39       | 85.1         | 7.1                      | 84.3             | 111            |
| 23 | JIRCAS-24            | 83.2         | 7.2                      | 90.7             | 118            |
| 24 | IR71525-19-1-1       | 101.6        | 6.1                      | 90.7             | 119            |
| 25 | B15209B-MR-1-3       | 89.4         | 6.6                      | 85.7             | 114            |
| 26 | B15209B-MR-17-1      | 90.4         | 5.2                      | 87.3             | 114            |
| 27 | B15408B-MR-4         | 99.3         | 4.7                      | 89.7             | 117            |
| 28 | B15231-MR-10-1       | 110.3        | 5.2                      | 95.3             | 122            |
| 29 | B15053F-PWR-2        | 95.2         | 4.4                      | 97.3             | 124            |
| 30 | B15209B-MR-12-1      | 91.8         | 6.0                      | 90.0             | 117            |
| 31 | B14908C-MR-1-25-1-3  | 95.8         | 8.1                      | 88.3             | 118            |
| 32 | B13643G-TB-26        | 97.2         | 7.9                      | 91.3             | 118            |
| 33 | B14191E-MR-3-61      | 100.7        | 6.3                      | 88.7             | 118            |
| 34 | B14192E-MR-2         | 99.3         | 4.9                      | 88.3             | 116            |
| 35 | B14192E-MR-33        | 103.8        | 5.1                      | 88.7             | 116            |
| 36 | B10580E-KN-28-1-1    | 86.0         | 4.4                      | 91.7             | 120            |
| 37 | Inpago 8             | 88.9         | 4.8                      | 84.0             | 111            |
| 38 | Limboto              | 97.0         | 5.6                      | 91.3             | 118            |
| 39 | Situ Patenggang     | 104.1        | 5.0                      | 89.7             | 117            |
| 40 | Jatiluhur            | 85.8         | 6.7                      | 90.0             | 117            |
The average weight of 1000 grains of the lines was 25.7 g, where this value was higher than the average of check varieties with a weight of 24.6 g. The line with the highest weight of 1000 grains was B15175C-TGB-39, where there were also 6 lines with a weight of 1000 grains which were not significantly different from, namely no. B15175C-TGB-23, IR71525-19-1-1, B11908F-TB-1-1, B15175C-TGB-16, B15175C-TGB-13, and B14192E-MR-2. Limboto variety was the highest 1000 grains compared to other check varieties (26.6 g).

### Table 2. Yield and yield components of upland rice lines, Tegalbuleud, Sukabumi, WS 2017

| No | Line            | Panicle length (cm) | No. of filled grain | Weight of 1000 grains (g) | yield (t/ha) |
|----|-----------------|---------------------|---------------------|---------------------------|--------------|
| 1  | B14168E-MR-2    | 24.5                | 96                  | 23.4                      | 1.85         |
| 2  | B11908F-TB-1-1  | 26.4                | 99                  | 29.7                      | 1.50         |
| 3  | B12825E-TB-2-4  | 25.8                | 94                  | 26.6                      | 1.34         |
| 4  | B11908D-MR-2-2-4| 21.9                | 47                  | 26.4                      | 0.77         |
| 5  | B11423G-MR-1-7  | 23.4                | 59                  | 27.1                      | 1.31         |
| 6  | B14129E-MR-5    | 25.7                | 102                 | 25.7                      | 1.77         |
| 7  | B14129E-MR-13   | 24.8                | 88                  | 25.8                      | 1.57         |
| 8  | B15053F-PWR-8   | 29.4                | 114                 | 20.9                      | 1.77         |
| 9  | B11957-RS*-2-3-2-18-2-SI-2-MR-2-PN-3-3 | 24.2 | 84 | 24.0 | 1.16 |
| 10 | B15175C-TGB-13  | 22.1                | 53                  | 29.0                      | 0.85         |
| 11 | B15175C-TGB-16  | 22.3                | 56                  | 29.3                      | 1.32         |
| 12 | B15175C-TGB-23  | 22.9                | 65                  | 30.7                      | 1.36         |
| 13 | B14957-MR-2-3-2 | 24.6                | 106                 | 24.3                      | 0.91         |
| 14 | B14958-MR-11-25-4-1 | 28.3 | 120 | 17.5 | 1.11 |
| 15 | B15114C-TB-22   | 25.3                | 86                  | 23.7                      | 1.29         |
| 16 | B15341-1B-TB-2  | 23.6                | 76                  | 26.3                      | 1.24         |
| 17 | B15341-1B-TB-29 | 25.5                | 91                  | 26.8                      | 1.70         |
| 18 | B14981B-TGB-4   | 26.1                | 119                 | 27.5                      | 2.08         |
| 19 | B15344B-TB-30   | 28.5                | 144                 | 25.1                      | 2.08         |
| 20 | B15344B-TB-34   | 25.1                | 105                 | 24.6                      | 1.65         |
| 21 | B14168E-MR-10-1 | 22.1                | 87                  | 22.6                      | 1.09         |
| 22 | B15175C-TGB-39  | 21.8                | 57                  | 31.2                      | 1.66         |
| 23 | JIRCAS-24       | 23.5                | 92                  | 24.5                      | 1.72         |
| 24 | IR71525-19-1-1  | 24.6                | 85                  | 30.5                      | 1.26         |
| 25 | B15209B-MR-1-3  | 25.6                | 100                 | 26.8                      | 1.57         |
| 26 | B15209B-MR-17-1 | 24.8                | 95                  | 25.8                      | 2.13         |
| 27 | B15408B-MR-4    | 24.2                | 88                  | 27.2                      | 1.38         |
The range of grain content per panicle of the lines was between 47-157 grains where B14908C-MR-1-25-1-3 had the highest amount of grain. This value was higher than the best check varieties Situpatenggang with 116 grain contents. The highest yield were Inpago 8 varieties with 2.55 t/ha and there were 8 lines with results not significantly different with Inpago 8 namely B14168E-MR-2, B15231-MR-10-1, B14981B-TGB-4, B15344B-TB-30, B15209B-MR-17-1, B14192E-MR-33 and B14908C-MR-1-25-1-3. However the selection of strains would be promising lines based not only on results but also by other characters that support high yield.

3.2. Correlation
Correlation character values with rice yields were used as an indicator for selecting improved rice varieties. Values of simple correlation showed that panicle length and number of grains per panicle were positively and significantly correlated with grain yield (Table 3). [12] founded that number of tillers per plant, days to maturity, and plant height had significant and positive correlation with grain yield. The selection on the basis of these characters can be helpful for improvement in rice grain yield and quality.

**Table 3.** Correlation among characters of upland rice lines

|       | PH    | NPT   | DF    | DH    | PL    | NFG   | WG    | Y     |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| PH    | 1.00000 | 0.08947 | -0.22831 | -0.23 | 0.22768 | 0.23657 | -0.03 | 0.13601 |
|       | 0.3332 | 0.0125 | 0.0133 | 0.0128 | 0.0096 | 0.7118 | 0.1402 |
| NPT   | 0.08947 | 1.00000 | -0.35608 | -0.35 | -0.01660 | 0.03061 | -0.06 | 0.09895 |
|       | 0.3332 | <0.001 | <0.001 | 0.8572 | 0.7400 | 0.5411 | 0.2823 |
The percentage of head rice averages above 46% with a range between 35% - 59% (Table 4). Head rice, which is healthy rice grains and defects that have a size greater than or equal to 75% of part of whole rice grains. The highest head rice of check variety was Limboto (56%), followed by Situpatenggang (55%). Some lines with head rice equivalent to check varieties were B15344B-TB-30, B12825E-TB-2-4, B15344B-TB-34, B15175C-TGB-39 and B15053F-PWR-8.

Some lines have milled rice percentage of more than 60%. The highest yield was 67% in lines no. 24 and 31 while other lines with yields above 60% were number B11908F-TB-1-1, B12825E-TB-2-4, B14129E-MR-5, B14129E-MR-13, B14957-MR-2-3-2, B15114C-TB-22, B15341-1B-TB-2, B15231-MR-10-1, B14191E-MR-3-61, B14192E-MR-2 and B14192E-MR-33.

The rice samples used in this experiment were comes from drying treatment. According to [8] the treatment can affect the quality of rice. The use of a drying machine can avoid contamination of sand or other impurities. In addition, the yield loss is less than 1%, lower than the drying method of 1.5-2.0%.

The rice texture test showed that there were 16 medium-textured lines, 15 tender, and 5 lines had hard texture. The hard-texture check was Jatiluhur and medium check varieties were Inpago 8, Limboto, Situpatenggang. Amylose levels of strains ranged from 16.6 (no. 32) to 26.56 (no. 3). The lower amylose content, the texture of the rice is getting fluffier and conversely the higher the amylose content of the rice texture will be more hard.

Medium texture check varieties had amylose content between 21% - 24%. Judging from the size of the rice, the average size of the rice strains tested was long (L), medium (M), medium (M) which meant long, while medium lining or limestone still appeared in the middle of the rice belly. Check varieties were mostly LMM except Inpago 8 with LMS shape and size. There were 6 lines, namely B11908D-MR-2-2-4, B15175C-TGB-13, B15175C-TGB-16, B15344B-TB-34, B15175C-TGB-39 and B14192E-MR-2, were detected as red rice. Line 15 as aromatic. [3] stated that low light during grain filling stage
affected physical appearance of rice grains by reducing milled rice rate and increasing the chalkiness rate. In addition, cooking qualities also decreased in response to low light.

Table 4. Grain quality of upland rice lines, Tegalbuleud, Sukabumi WS 2017

| No | Galur             | Milled rice | Amylose (%) | Rice texture | L  | S  | C  | Description |
|----|-------------------|-------------|-------------|--------------|----|----|----|-------------|
| 1  | B14168E-MR-2      | 53          | 23.84       | 3.2          | M  | M  | M  |             |
| 2  | B11908F-TB-1-1    | 62          | 26.44       | 4.0          | L  | M  | M  |             |
| 3  | B12825E-TB-2-4    | 62          | 26.56       | 3.8          | L  | M  | M  |             |
| 4  | B11908D-MR-2-2-4  | 50          | 19.44       | 2.0          | L  | M  | M  | Red rice    |
| 5  | B11423G-MR-1-7    | 54          | 19.68       | 2.2          | L  | M  | M  |             |
| 6  | B14129E-MR-5      | 60          | 19.52       | 2.0          | L  | M  | M  |             |
| 7  | B14129E-MR-13     | 64          | 21.68       | 2.8          | L  | M  | M  |             |
| 8  | B11505F-PWR-8     | 60          | 23.76       | 3.0          | M  | M  | M  |             |
| 9  | B11957-RS*-2-3-2-18-2-SI-2-MR-2-PN-3-3 | 52 | 24.88 | 3.8 | hard | L | M | M | Red rice |
| 10 | B15175C-TGB-13    | 35          | 22.72       | 2.8          | L  | M  | M  | Red rice    |
| 11 | B15175C-TGB-16    | 49          | 17.52       | 1.8          | L  | M  | M  |             |
| 12 | B15175C-TGB-23    | 42          | 19.36       | 2.0          | L  | M  | M  |             |
| 13 | B14957-MR-2-3-2   | 62          | 24.00       | 3.0          | L  | M  | M  |             |
| 14 | B14958-MR-11-25-4-1 | 58 | 24.48 | 3.7 | hard | L | M | M |             |
| 15 | B15114C-TB-22     | 60          | 23.04       | 3.1          | L  | M  | M  | Aromatic    |
| 16 | B15341-1B-TB-2    | 63          | 21.52       | 2.8          | L  | M  | M  |             |
| 17 | B15341-1B-TB-29   | 49          | 19.36       | 2.1          | L  | M  | M  |             |
| 18 | B14981B-TGB-4     | 58          | 18.96       | 2.0          | L  | M  | M  |             |
| 19 | B15344B-TB-30     | 57          | 20.72       | 2.5          | L  | M  | M  |             |
| 20 | B15344B-TB-34     | 57          | 22.08       | 2.8          | L  | M  | M  | Red rice    |
| 21 | B14168E-MR-10-1   | 45          | 25.60       | 3.8          | L  | M  | M  |             |
| 22 | B15175C-TGB-39    | 56          | 21.12       | 2.6          | L  | M  | M  | Red rice    |
| 23 | JIRCAS-24         | 48          | 25.52       | 3.8          | L  | S  | S  |             |
| 24 | IR71525-19-1-1    | 67          | 18.64       | 1.8          | M  | S  | S  |             |
| 25 | B15209B-MR-1-3    | 37          | 20.96       | 2.5          | L  | M  | M  |             |
| 26 | B15209B-MR-17-1   | 38          | 17.28       | 2.1          | L  | S  | S  |             |
| 27 | B15408B-MR-4      | 55          | 19.36       | 2.2          | L  | S  | S  |             |
| 28 | B15231-MR-10-1    | 66          | 23.92       | 3.2          | L  | M  | M  |             |
| 29 | B15053F-PWR-2     | 59          | 22.16       | 2.8          | L  | M  | S  |             |
| 30 | B15209B-MR-12-1   | 47          | 18.40       | 2.0          | L  | S  | S  |             |
| 31 | B14908C-MR-1-25-1-3 | 67 | 20.00 | 2.2 | tender | M | M | S |             |
| 32 | B13643G-TB-26     | 59          | 16.64       | 2.0          | L  | M  | M  |             |
| 33 | B14191E-MR-3-61   | 66          | 20.72       | 2.6          | L  | M  | M  |             |
| 34 | B14192E-MR-2      | 62          | 16.96       | 1.8          | L  | M  | M  | Red rice    |
| 35 | B14192E-MR-33     | 65          | 21.52       | 2.8          | L  | S  | S  |             |
| 36 | B10580E-KN-28-1-1 | 54          | 18.64       | 2.0          | L  | M  | S  |             |
| 37 | Inpago 8          | 56          | 21.37       | 3.0          | M  | M  | S  |             |
Based on the yield components and the grain quality there were 6 lines may be filed as a material for multi-location test to obtain information about the potential and stability of the yield from the various locations, i.e. B14981B-TGB-4, B15344B-TB-30, B15175C-TGB-39, B15209B-MR-17-1, B14908C-MR-1-25-1-3 and B14192E-MR-33. Those lines are expected to become new shade tolerant varieties.

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