Tidal swamp tolerant rice lines: climate change adaptive varieties

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Abstract. Weather phenomenon and erratic rainfall are some of the symptoms of global climate change. These challenges attempt to increase rice production in tidal swamps or submerge land in the long term. An effort to form tolerant rice varieties to stress in tidal swampland has been carried out through crossing between superior varieties and local rice. This study aims to analyze the results of several promising rice lines and search for the potential rice lines to be released as new tidal swampland varieties. The experiment was carried out in tidal swamp rice area centers, in Karang Agung, South Sumatra, Balandean, South Kalimantan and in Indramayu, West Java Indonesia. Fourteen rice lines and four check varieties namely IR42, IR64, Inpara 8 and Inpara 9 were used. Field experiments used a Randomized Complete Block Design (RCBD) with four replications. Results showed that the environment, genotype, and interaction between environmental genotypes had a significant influence on all characters. The appearances of the lines were superior in Karang Agung and less well on Balandean. The yield was positively correlated with plant height, the number of productive tillers and filled grains per panicle. There were five lines with a high yield equivalent to the best check varieties, namely Inpara 9, IR 102860-8: 66-BB, IR 102860-8: 42-BB, IR 101465-8: 23, IR 101465-5: 25, and B13522E-KA-5-B.

1. Introduction
Anticipating the effects of climate change on rice productivity include the development of superior rice varieties that are resistant to drought, submerged, pest and disease. Some categories of climate change that can reduce agricultural production such as extreme temperatures, heat waves, drought, storms, rain to cause flooding. Rice productivity in Indonesia is more sensitive to changes in rainfall and maximum temperature as one of the climate change indicators [1]. The sustainable increase of rice production for food security will require efforts to enhance the capacity of rice production systems to adapt to global climate change as well as to mitigate the effects of rice production on global warming [2]. On the other hand, the utilization of agricultural land resources with various other economic sectors is one of the triggers for the land conversion as well as an indication of land quality degradation, which has resulted in decreased productivity [3]. Land competition between the agricultural sector, housing, and industrial sectors has become a challenging concern [4].

Agricultural development in tidal swamps is one of the efforts in responding to the challenges of increasing agricultural production, especially rice production as a staple food in Indonesia [5,6]. Suitable area of tidal swamps for rice plant reaches 6.10 million ha, with 3.42 million ha in tidal swamps and 2.67 million ha in peat lands [7]. Tidal swamps have good prospects for development into productive
agricultural land with the application of appropriate technological innovations. However, the use of tidal swamps for food crop cultivation, especially rice, faces several problems, including low soil fertility, acidic soil reactions, pyrite, high levels of Al, Fe, Mn, and organic acids, P deficiency, and poor base of Ca, K, Mg, also inhibited microbial activity. The selection of appropriate rice varieties is, therefore, another technical option for adaptation to global climate changes [9].

Tidal swamps can support the national food production because of availability of various technological innovations [8], such as: (1) water and soil management technologies, including micro-water management, land management, amelioration and fertilization; (2) new superior varieties that are more adaptive and productive; and (3) agricultural tools and machinery suitable for the typology of the land. However, the development and optimization of tidal swampland use also face non-technical problems, including funds, labor availability, and farmer technology mastery [2]. This experiment aimed to investigate the yield production and determine the best lines in the tidal swamp area.

2. Material and method

2.1 Time and place
The yield trial experiment was carried out at three locations in 2017. Those locations were, the tidal swamp experimental farm in Balandean, South Kalimantan at 20.1 meter above sea level (masl) in first planting season 2017 and Karang Agung, South Sumatra at 13.9 masl in second planting season 2017 and also in flood-prone areas in Indramayu, West Java Indonesia at 6 asl, in second planting season 2017.

2.2 Materials
The lines evaluated as many as 14 lines, which were selected lines from the previous year's and four check varieties, namely IR42, IR64, Inpara 8 and Inpara 9.

2.3 Experiment design
In each location, the field experiment used a Randomized Block Design (RBD) with four replications, 4 m x 5 m plots, 25 cm x 25 cm spacing, 21-25 days of seedlings and 2-3 seedlings per clump. Fertilizing is done twice, namely: I. 0 weeks after planting: 75 kg Urea + 150 kg/ha Phonska. II. 2-4 MST: 75 kg Phonska/ha. Fertilizer was applied after weeding. Eradication of pests and diseases is done if needed according to field conditions. Data analysis with analysis of variance and LSD as a further test.

2.4 Observation
Variables observed were plant height, number of productive tillers, age of flowering plants, age of harvest, number of filled and empty grains per panicle, weight of 1000 filled grains (14% water content), grain yield per plot (14% moisture content), pest and disease attacks, the level of Fe poisoning according to the Standard Evaluation System for Rice (SES) [10].

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

3. Results

3.1 Analysis of variance
The analysis of variance showed that location and genotype were significantly affected all characters' plant height, number of the productive tiller, number of filled grain and yield. Replication was not significantly different affected the number of filled grain per panicle and yield. The interaction between genotype and location was not significantly affected the number of productive tillers (Table 1).
Table 1. Mean square of combine analysis of rice lines characters in three locations in 2017.

| Source of variation | df  | Plant height | Number of productive tillers | Number of filled grain per panicle | Yield |
|---------------------|-----|--------------|-------------------------------|-----------------------------------|-------|
| Location (L)        | 2   | **           | **                            | **                                | **    |
| Replication(location) | 9   | **           | **                            | ns                                | ns    |
| Genotype (G)        | 17  | **           | **                            | ns                                | ns    |
| G x L               | 34  | **           | ns                            | **                                |       |

Note. ** significant, ns not significant at 5% probability by the F test.

3.2. Field performance

Characters of rice lines in three locations were shown in Table 2. Yield trial experiment at Baladean KP, Kab. Barito Kuala gained the grain yields that range from 1.03 to 2.35 t/ha, with plant height ranged between 79 to 91, the number of productive tillers was 10-14, and the number of filled grain per panicle ranged 43 to 68 grains. IR42 was the best check with yield 1.84 t/ha. The field performance of the lines as shown in Figure 1.

In Karang Agung, the grain yield ranged from 2.71 to 8.44 t/ha. The yield of INPARA 9 was 3.84 t/ha, equivalent to INPARA 8. All of the lines were not significantly different from INPARA 9 as the best check (Table 3). IR 101465-5:25 and B13522E-KA-5-B were the best lines with the yield up to 8.84 and 5.59 t/ha, respectively. The height of the plants ranged between 87-133 cm. Plant height was above 100 cm and suitable for swamp rice, except IR102860-12: 6-B-B which may be dwarf. The number of productive tillers ranged between 13 to 19 stems, while the age of the plants was included in the early maturity criteria. The lines approximately had a higher number of filled grains per panicle, with B13522E-KA-5-B was the highest.

Indramayu was a flood-prone area. The grain yield ranged between 1.28 to 3.27 t/ha. INPARA 9 has results equivalent to other check varieties. Lines that give the highest yield were IR102860-8: 42-B-B, B14308E-KA-12, B13522E-KA-5-B, and B13926E-KA-44.
Table 2. Lines performance in three locations* 2017.

| No | Genotype                  | Plant height (cm) | No of prod tiller | No of filled grain | Yield (t/ha) |
|----|---------------------------|-------------------|-------------------|-------------------|--------------|
|    |                           | BLN   | KRA   | IDR   | BLN   | KRA   | IDR   | BLN   | KRA   | IDR   | BLN   | KRA   | IDR   |
| 1  | IR 102860-8:66-B-B        | 83    | 94    | 118   | 12    | 18    | 15    | 52    | 160   | 98    | 2.11  | 5.39  | 2.99  |
| 2  | IR 102860-12:6-B-B        | 89    | 87    | 129   | 14    | 16    | 15    | 52    | 138   | 111   | 2.18  | 3.58  | 2.58  |
| 3  | IR 102860-8:42-B-B        | 89    | 97    | 117   | 11    | 16    | 17    | 52    | 128   | 118   | 2.06  | 5.26  | 3.12  |
| 4  | IR 101465-8:23            | 91    | 92    | 120   | 12    | 15    | 15    | 59    | 120   | 119   | 1.48  | 5.28  | 3.10  |
| 5  | IR 101465-5:25            | 85    | 99    | 119   | 11    | 16    | 12    | 56    | 145   | 116   | 1.52  | 8.44  | 3.02  |
| 6  | B14308E-KA-12             | 84    | 113   | 118   | 10    | 17    | 16    | 55    | 148   | 116   | 1.08  | 4.36  | 3.35  |
| 7  | B13983E-KA-12-2           | 79    | 114   | 114   | 10    | 16    | 16    | 60    | 142   | 104   | 1.35  | 4.41  | 2.57  |
| 8  | B13134-4-MR-1-KA-3-4      | 88    | 113   | 109   | 11    | 13    | 14    | 59    | 142   | 77    | 1.03  | 3.70  | 2.48  |
| 9  | B13522E-KA-5-B            | 84    | 126   | 116   | 10    | 13    | 15    | 55    | 205   | 95    | 2.35  | 5.59  | 3.27  |
| 10 | B14333E-KA-48             | 84    | 110   | 115   | 10    | 14    | 10    | 67    | 138   | 81    | 1.84  | 4.94  | 1.28  |
| 11 | B14357E-KA-35             | 86    | 109   | 102   | 10    | 13    | 13    | 58    | 145   | 56    | 1.57  | 3.99  | 2.36  |
| 12 | B14362E-KY-13             | 90    | 97    | 124   | 13    | 19    | 14    | 43    | 107   | 122   | 1.08  | 2.90  | 2.03  |
| 13 | B13952E-KA-5              | 88    | 133   | 126   | 12    | 13    | 14    | 68    | 170   | 108   | 1.84  | 4.74  | 1.48  |
| 14 | B13926E-KA-44             | 81    | 108   | 115   | 10    | 17    | 14    | 50    | 106   | 81    | 1.57  | 4.74  | 3.13  |
| 15 | Inpara 8                  | 80    | 112   | 125   | 9     | 14    | 12    | 44    | 151   | 110   | 0.89  | 3.77  | 2.36  |
| 16 | Inpara 9                  | 80    | 114   | 113   | 12    | 15    | 14    | 46    | 130   | 93    | 1.31  | 3.84  | 3.41  |
| 17 | IR42                      | 74    | 106   | 116   | 9     | 18    | 17    | 50    | 132   | 78    | 1.84  | 3.20  | 1.73  |
| 18 | IR64                      | 81    | 85    | 100   | 10    | 17    | 14    | 46    | 85    | 64    | 0.98  | 2.71  | 3.13  |
|    | Average                   | 84    | 106   | 116   | 11    | 16    | 14    | 54    | 138   | 97    | 1.56  | 4.49  | 2.63  |
|    | LSD (5%)                  | 10    | 10    | 6     | 3     | 3.3   | 5     | 14    | 31.0  | 21    | 0.60  | 1.80  | 0.86  |
|    | CV (%)                    | 8.6   | 6.37  | 3.4   | 16.9  | 15.1  | 22.8  | 18.5  | 15.8  | 15.3  | 26.9  | 28.3  | 23.1  |

*BLN = Balandean, KRA=Karang agung, IDR=Indramayu
From the three locations, the lines appear better in Karang Agung, then in Indramayu and Balandean. The potential yield of the tested lines could reach an average of 4.5 t/ha in Karang Agung, the number of filled grains reached an average of 138.4 grains and a total of 15.5 tillers. The high percentage of filled grain is so important as one of the yield components. Irmawati et al. 2015 reported a high percentage of empty grains (± 40%) had initiated high yield loss resulted only in 9.5 g yield/hill, approximately equal to 4.75 tons/ha.

Table 3. Mean value, heritability (H) and proportion heritability (under H) of the characters in each locations and combine of the three locations in 2017.

| Location   | Plant height | H   | Number of productive tillers | H   | Number of filled grain | H   | Yield | H   |
|------------|--------------|-----|------------------------------|-----|------------------------|-----|-------|-----|
| Indramayu  | 116.4c       | 0.93| 14.3b                        | 0.18| 97.2b                  | 0.86| 2.6b  | 0.78|
| Kr Agung   | 106.2b       | 0.93| 15.5a                        | 0.61| 138.4a                 | 0.83| 4.5a  | 0.76|
| Balandean  | 84.1a        | 0.34| 10.8c                        | 0.47| 53.9c                  | 0.52| 1.6c  | 0.78|
| Combine    |              | 0.70|                             | 0.94|                       | 1.62|       | 2.00|

LSD (%) 2.03 5.37 0.84 0.28

Note. Within a column for each character, means followed by the same letters were not significantly different according to LSD 5%

The heritability in each environment and the proportion value used to determine a suitable environment for selecting a character [11]. Previously, identification was needed in one environment that approached the selection conditions in the combined environment. Comparative values that are close to one or more than one are assumed to be the most appropriate environment for selection. The highest proportion value for all characters is owned by Karang Agung location, so that location is the most suitable as a selection environment for all characters. Planting conditions in Baladean and Indramayu were not suitable as the location for selection experienced drought and immersion and Fe stresses that decreasing yield significantly (Table 3).

However, the development of rice varieties that have not only high-yielding potential, but also a good degree of tolerance to high temperature, salinity, drought and flood, would be very helpful under the environment of global warming [2]. In addition to the use of flooding tolerance variety, proper fertilization strategy was also given an impact on the increase of rice growth and development under flooding stress conditions [12]. Jumakir dan Endrizal [13] reported that the implementation of the cultivation technology approach can support an increase in production of rice in the form of new varieties of rice, in the case of Inpara 3 variety that could gain with the yield of 7.04 t/ha than without cultivation technology implementation. Educated farmers for technical efficiency factor found significantly influence the rice production [14].

3.3 Correlation

The simple correlation between characters is important in plant breeding that can be used as a tool for indirect selection. The results of correlation analysis showed in Table 4 revealed that there was a positive and highly significant correlation between plant height with the number of the productive tiller \(r=0.26045\), and the number of filled grain per panicle \(r=0.60208\) and yield \(r=0.32329\). Other characters that had a positive relationship with grain yield were the number of productive tillers \(r=0.26242\) and the number of filled grain per panicle \(r=0.69367\). It indicated that to determine the lines with the highest yield can be determined through data from those three characters as in line with a finding result by Sharifi and Ebadi [15] and Anis et al. [16]. However, Sreedhar and Reddy [17] showed
contrary results by reposted that there was a significant negative correlation between the number of filled grains per panicle and yield.

**Table 4.** Correlation between plant characters.

|                     | Plant height | No of productive tiller | No of filled grain per panicle | Yield   |
|---------------------|--------------|--------------------------|--------------------------------|---------|
| Plant height        | 1.00000      |                          |                                |         |
| No of productive tiller | 0.26045**   | 1.00000                  |                                |         |
| No of filled grain per panicle | 0.60208** | 0.27445**               | 1.00000                        |         |
| Yield               | 0.32329**    | 0.26242**                | 0.69367**                      | 1.00000 |

*Note** ** indicate significance at 0.01 probability levels.

4. Conclusion

There were five lines with high yield potential in tidal swamps to deal with climate change that equivalent to the best check Inpara 9, namely IR 102860-8: 66-BB, IR 102860-8: 42-BB, IR 101465-8: 23, IR 101465-5: 25, and B13522E-KA-5-B. Plant height characteristics, the number of productive tillers and the number of grain-filled can be used as secondary criteria to get high yields. Karang Agung is the appropriate location for strain selection in the tidal swampland.

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