Application of Organic and Bio-Fertilizer Containing Mycorrhiza to Increase Yield of Several Promising Lines of Red Rice in Aerobic System

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Abstract

This study aimed to examine the effect of organic and bio-fertilizer containing arbuscular mycorrhizal fungi (AMF) on growth and yield of various promising lines of red rice grown in aerobic systems on raised-beds. The field experiment was carried out on farmers’ land in Beleke Village, Gerung, West Lombok, Indonesia, from May to September 2018. The experiment was designed according to the Split Plot design with 3 blocks two treatment factors, namely red rice genotypes (G) as the main plot factor, consisting of 4 promising lines (G1 = MG4, G2 = MG10, G3 = AM4, and G4 = AM10), and application of organic and bio-fertilizer "Technofert" (containing AMF) in addition to NPK fertilizers as the sub-plot factor, consisting of 3 levels of treatment (P0 = without organic or bio-fertilizer, and P1 = with organic fertilizer using bokashi (EM-4 fermented cattle manure), and P2 = with organic and bio-fertilizer). The red rice seeds were pre-germinated, which was then dibbled on permanent raised-beds with a base spacing of 25 x 20 cm, which was then modified into a double-row pattern. The results indicated that the significant effects of organic and bio-fertilizer was mainly due to the presence of AMF in the bio-fertilizer, and application of the bio-fertilizer significantly increased production capacity of the promising lines of red rice, especially in relation to number of filled panicles per clump, biomass weight, and percentage number of productive tillers. There was a tendency that the highest production capacity was in the AM10 promising line (G21).

Keywords: red rice, aerobic rice system, arbuscular mycorrhiza, organic fertilizer
1. Introduction

Rice is normally grown under flooded system, so that irrigation water requirement is very high. Yaligar et al. (2017) reported that conventional techniques of growing rice required irrigation water of up to 20260 m$^3$/ha, while dry seeded direct planting only required 4260 m$^3$/ha. In addition to wasting of irrigation water, flooded rice system causes a lot of disadvantages such as pollution of water in the downstream areas due to seepage, runoff and percolation from paddy water during growth of rice plants, especially during fertilizer and pesticide application. The anaerobic conditions due to flooding can cause rice fields to produce methane and N$_2$O gas emissions (Bouman et al., 2007). N fertilization with Urea also becomes inefficient due to losses through seepage and percolation water in addition to loss of Urea N through volatilization to NH$_3$ gas, which can reach 50% of Urea fertilizer applied (Buresh and De Datta, 1990).

In addition to physical and chemical disadvantages, growing rice under flooded conditions also reduces population of arbuscular mycorrhizal fungi (AMF) in paddy soil following flooded conditions of growing rice, when compared with following upland rice (Wangiyana et al., 2006). In fact, rice plants also need a good symbiosis with AMF for better nutrition, as has been reported by many researchers. Dhillion and Ampornpan (1992) for example reported that AMF inoculation in the nursery not just increased P uptake by rice seedlings but also increased uptake of other nutrients such as K, Ca, Fe, Cu, Na, B, Zn, Al, Mg and S. Solaiman and Hirata (1995) showed that AMF inoculation significantly increased grain and shoot dry matter as well as N, P and K concentration in the unhulled grains of rice. Solaiman and Hirata (1996) also indicated that AMF inoculation of rice seedlings in the nursery increased grain yield and contents of P and micronutrients in the grains such as Zn, Cu, Fe and Mn.

In order to reduce the use of irrigation water, there have been several non-conventional techniques developed in more recently. One of which is the System of Rice Intensification (SRI), in which rice is irrigated under intermittent short flooding and drying during the vegetative growth stages followed with thin flooding during the reproductive growth stages, and this results in significantly higher grain yield under SRI compared with under conventional technique of growing rice (Uphoff, 2003). Another technique of growing rice is aerobic rice system (ARS), in which rice is grown under non-flooded, non- puddled and non-saturated soil conditions (Bowman 2001; Prasad, 2011). However, grain yield of rice
under ARS is normally lower than under conventional technique, especially when rice is
grown in monoculture (Nie et al., 2012). Since rice is not flooded, mycorrhizal symbiosis
should be better under ARS than under conventional technique of growing rice.

This research aimed to examine the effects of organic and AMF application on growth
and yield of several promising lines of red rice under aerobic rice system.

2. Materials and method
2.1 Treatments and the experimental design

In this study, the field experiment was carried out on farmers' land in Beleke Village,
Gerung District, West Lombok Regency, NTB Province, Indonesia, from May to September
2018. Experiments were designed according to Split Plot design with 3 blocks and two
treatment factors, namely red rice promising lines (G) as the main plot, consisting of 4
selected lines (G1 = MG4, G2 = MG10, G3 = AM4, and G4 = AM10), and organic and bio-
fertilizer application using the bio-fertilizer "Technofert" which contains mixed species of
arbuscular mycorrhizal fungi (FMA) as subplots, consisting of three treatment levels (P0=
without organic or bio-fertilizers; P1= with organic fertilization using bokashi (EM-4
fermented cattle manure), and P2= with organic and bio-fertilizer application at the time of
planting rice seeds). Pre-germinated red rice seeds were planted by dibbling them on
permanent raised-beds, with a basic spacing of 25 x 20 cm, which was then modified into a
double-row pattern.

2.2 Implement of the field experiment

Before plotting and making raised-beds, the land was cultivated with once plowing
and once leveling, then raised-beds were made with a bed surface size of 2.0 m x 1.0 m,
separated by a furrow of 40 cm wide on the top of the beds (and 20 cm at the base of the
furrow) with a bed height of 25 cm. At planting 3-4 pre-germinated seeds were dibbled at a
distance of 20 cm within rows and 20 cm between each row of a double-row but 30 cm
between double-rows (double-row modification of 25 x 20 cm planting distance). AMF in the
bio-fertilizer and organic fertilizer were applied at planting by placing them in the planting
holes, and the pre-germinated red rice seeds were placed above them, and then covered with
thin soil layer. For the treatments receiving organic fertilizer (P1 & P2), each planting hole
was filled with 40 g bokashi (8 ton/ha), while for those receiving AMF application, each
planting hole was filled with 5 g “Technofert” bio-fertilizer in the position below the bokashi. Technofert was supplied by PT Mikata Mandiri, Jakarta. For application of NPK fertilizer (P0, P1 & P2), the Phonska (15-15-15) fertilizer was used, with a dose of 300 kg/ha applied by dibbling at 7 days after planting (DAP) rice seeds, followed with dibbling Urea (45% N) fertilizer at 45 DAP with a dose of 100 kg/ha. Irrigation water was supplied every 5-7 days by flowing water through the furrows surrounding the raised-beds. Harvest was done at 110 DAS.

2.3 Observation variables and data analysis

Observation variables included growth variables and yield components of the rice plants measured from four clumps of rice plant samples per bed. Data were analyzed using Analysis of Variance (ANOVA) and Honestly Significant Difference test (Tukey's HSD) at the 5 percent level, using the Statistical program CoStat for Windows ver. 6.303.

3. Results

The summary of ANOVA results in Table 1 shows that organic and bio-fertilization on various red rice promising lines significantly affected the number of panicles per clump, weight of dry straw per clump and percentage number of productive tillers. In terms of the rice genotypes used, the differences between genotypes were significant in almost all the observation variables, except in plant height at anthesis and the percentage number of productive tillers per clump. However, there were no significant interaction effects between the two treatment factors on all observation variables.

Table 1. Summary results of ANOVA on plant height and tiller number at anthesis, and number of filled panicles, stems, straw dry weight and percentage number of filled panicles per clump at harvest of various promising lines of red rice

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Plant height</th>
<th>Tiller number per clump</th>
<th>Panicle number per clump</th>
<th>Stem number per clump</th>
<th>Dry straw weight per clump</th>
<th>%-productive tillers per clump</th>
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<tr>
<td>Block</td>
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Fertilization

<table>
<thead>
<tr>
<th>(P)</th>
<th>ns</th>
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<tbody>
<tr>
<td>Red rice lines (G)</td>
<td>ns</td>
<td>*</td>
<td>*</td>
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**Remarks:** ns = non-significant; *, **, *** = significant respectively at p-value <0.05, p-value <0.01 and p-value <0.001

Further analysis using means comparison (Table 2), indicated that the presence of AMF in the fertilization treatment mostly results in higher performance of the red rice genotypes tested, when compared with other fertilization treatment, especially those with no AMF application. For example, panicle number per clump, which is a basis for yield quantity, is significantly higher in the P3 treatment than in the P1 or P2 treatment. The percentage of productive tillers, i.e. ratio between number of filled panicles per clump and number of tillers per clump, is also significantly higher in the P3 treatment than in the P1 treatment. These all indicated an increase in production capacity due to application of the bio-fertilizer “Technofert” containing mixed species of AMF, indicating positive effects of AMF on performance of those red rice genotypes.

Table 2. Averages of plant height and tiller number at anthesis, and number of filled panicles, stems, straw dry weight and percentage number of filled panicles per clump at harvest for each fertilization treatment and genotype of red rice

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height (cm)</th>
<th>Tiller number per clump</th>
<th>Panicle number per clump</th>
<th>Stem number per clump</th>
<th>Weight of dry straw (g/clump)</th>
<th>%-productive tillers per clump</th>
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<tbody>
<tr>
<td>P1</td>
<td>90.5 a</td>
<td>25.4 a</td>
<td>20.9 b</td>
<td>24.4 a</td>
<td>29.65 b</td>
<td>85.7 ab</td>
</tr>
<tr>
<td>P2</td>
<td>92.3 a</td>
<td>25.4 a</td>
<td>21.7 b</td>
<td>24.7 a</td>
<td>29.03 b</td>
<td>87.9 ab</td>
</tr>
<tr>
<td>P3</td>
<td>96.2 a</td>
<td>27.1 a</td>
<td>23.5 a</td>
<td>25.4 a</td>
<td>36.70 a</td>
<td>92.3 a</td>
</tr>
<tr>
<td>HSD 0.05</td>
<td>5.9</td>
<td>2.1 a</td>
<td>1.7 a</td>
<td>1.4 c</td>
<td>2.65 c</td>
<td>4.6 c</td>
</tr>
<tr>
<td>G04</td>
<td>94.6 a</td>
<td>24.7 b</td>
<td>20.2 b</td>
<td>23.2 c</td>
<td>29.35 b</td>
<td>87.2 a</td>
</tr>
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**4. Discussion**

Based on the effects of fertilization treatments, it can be seen from Table 2 that the P3 treatment, namely the combination of NPK fertilizer at recommended doses, bokashi organic fertilizer and AMF bio-fertilizer, in general results in the highest averages especially in terms of the number of filled panicles per clump, weight of dry straw per clump and percentage of number of productive tillers. Those averages are also mostly higher in the P3 than in the P2 treatment, which both received both NPK and organic fertilizer, except bio-fertilizer application. This means that those significant differences were caused by the presence of AMF in the bio-fertilizer. As has been reported by many researchers rice plants are responsive to AMF inoculation, which means that establishment of symbiosis between rice and AMF is beneficial for rice. The most common beneficial effects of AMF symbiosis in rice is in relation to nutrient acquisition in which mycorrhizal rice plants can take up more nutrients such as N, P, K, and other nutrients compared with non-mycorrhizal rice plants (Dhillion and Ampornpan, 1992; Solaiman and Hirata, 1995, 1996; Smith dan Read, 2008). Solaiman and Hirata (1995) also indicated higher transfer of N and P nutrients from soil and/or shoot to grains which facilitated grain filling process resulted in higher harvest index in mycorrhizal compared with non-mycorrhizal rice plants.

The four genotypes of red rice promising lines used in this research were results of selection from 23 genotypes tested in previous research, which selection was based on grain yield components when grown in intercropping with soybean under aerobic rice system. G04 and G10 are upland red rice lines while G15 and G21 are amphibious red rice lines. From Table 2, it can be seen that their performance are significantly different except for plant height and percentage number of productive tiller per clump. However, in terms of tiller number and panicle number per clump, the averages tend to be highest on G21 compared with other genotypes. When grown in conventional technique of growing rice, Aryana and **

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<tbody>
<tr>
<td>G10</td>
<td>90.7</td>
<td>a</td>
<td>27.2</td>
<td>a</td>
<td>23.2</td>
<td>a</td>
</tr>
<tr>
<td>G15</td>
<td>90.7</td>
<td>a</td>
<td>24.7</td>
<td>ab</td>
<td>21.3</td>
<td>ab</td>
</tr>
<tr>
<td>G21</td>
<td>95.9</td>
<td>a</td>
<td>27.2</td>
<td>a</td>
<td>23.5</td>
<td>a</td>
</tr>
<tr>
<td>HSD 0.05</td>
<td>6.9</td>
<td>a</td>
<td>2.4</td>
<td></td>
<td>2.5</td>
<td></td>
</tr>
</tbody>
</table>

\[1\] Mean values followed in each column by the same letters are not significantly different between levels of a treatment factor based on its Tukey’s HSD at 5% level of significance.
Wangiyana (2016) also found that this G21 (identified as G10(F2BC4A52-42)) showed the highest average of grain yield.

Therefore, based on the results obtained it can be concluded that the significant effects of organic and biological fertilization with Technofert containing AMF mainly due to the influence of AMF in the bio-fertilizer applied with the organic fertilizer, and the application of the bio-fertilizer could significantly increase the production capacity of various promising lines of red rice, especially in relation to the average number of filled panicles per clump, the weight of dry biomass and the percentage number of productive tillers. Among the four selected lines, there was a tendency that the highest production capacity was in the AM-10 (or G21).

5. Acknowledgement

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6. References


