The effect of organic waste application on some soil physical properties, growth and yield of red rice between conventional and aerobic irrigation system on raised-beds

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Abstract. The objective of this study was to evaluate the effect of organic waste application on some soil physical properties, growth and yield of red rice between conventional and aerobic irrigation systems on permanent raised-beds. The experiment was carried out in May to August 2020, under Split Plot design with two factors namely techniques of rice cultivation (conventional, T1; aerobic irrigation system, T2) as main plots, and organic wastes (L0= without organic waste, L1= rice husk, L2= rice husk ash, L3= rice husk ash and cattle manure) as the subplots. Results indicated that both treatment factors affected some physical properties of the soil, growth, and yield of red rice. Some variables showed significant interaction namely soil bulk density, red-rice height, leaf number and dry straw weight. Changing rice cultivation technique from conventional to aerobic irrigation system significantly reduced soil bulk density, especially under application of rice husk ash together with cattle manure or without cattle manure, resulting in the highest red rice grain yield of 37.78 g/clump whereas under conventional without organic wastes, grain yield was only 21.27 g/clump. On average, changing from conventional technique to aerobic irrigation system could increase red rice grain yield by 40.13%.

1. Introduction
In Indonesia the most common staple food is rice. Lately, many people are switching from consumers of white rice to red rice. This is partly because red rice has better nutritional content than white rice. The fibre content, essential fatty acids and some vitamins are higher in red than white rice. In addition, the high anthocyanin content of around 0.33-1.39 mg/100 g makes red rice more attractive because it can prevent several diseases such as diabetes, cancer, cholesterol, hypertension, coronary heart disease, and symptoms of stroke [1].

Amphibious red rice is one of the lines being developed [2], which can be cultivated under conventional (flooded) or under aerobic systems. Like other types of rice, red rice is a type of rice that is relatively easy to grow. However, there are several obstacles faced by many farmers, including limited water sources, degradation of soil fertility, and land availability due to land use conversion. Some forms of fertility degradation are worse soil physical properties.

Most rice farmers in Indonesia, including farmers in Lombok, apply conventional planting methods, by planting rice with intensive tillage, implementation of a transplanting system and flooding the rice soil. This technique is very wasteful in the use of irrigation water, and requires a large amount of money. In addition, the conventional cultivation technique also decreases the quality of soil physical properties,
such as soil compaction, reducing soil porosity, and reducing soil ability to retain water as well as nutrients. Aryana and Wangiyana [2] reported that conventional cultivation systems have low average productivity. In addition, non-rice food crops such as soybean direct seeded following conventional rice yielded significantly lower than following aerobic-irrigated rice [3], and although when following conventional rice, yield of soybean can be increased by inoculation with *Rhizobium* bacteria and AMF (arbuscular mycorrhizal fungi) [4].

Growing rice in an aerobic irrigation system can be done by dibbling rice seeds on permanent raised-beds and irrigating the crops through the furrow surrounding the raised-beds, and this technique provides an advantage to establish rice-legume intercropping in order to increase rice yield [5, 6]. Furthermore, Ma'shum et al. [7] (2009) reported that the permanent bed system can be an alternative solution to reduce waste of water use, and adapt to climate conditions with low and erratic rainfall. The two systems have been proven to be able to save water, as well as to improve the stability of soil aggregates [8, 9].

Organic matter, including organic wastes from agricultural activities, plays an important role in improving soil fertility, through its role as a granulator and nutrient source. For example, organic matter applied to a soil of massive structure could change soil structure to become crumbly and relatively light. Water absorption by the soil could be faster so that it can be expected to help overcome the problem of water scarcity in rice cultivation. Harahap et al. [10] and Kiswondo [11] reported that rice husk and rice husk ash improved nutrient availability for plant growth. The objective of this study was to examine the effect of organic waste application on some soil physical properties and yield of red rice between conventional and aerobic irrigation systems on permanent raised-beds.

2. Materials and Method

This experiment was carried out in May - August 2020, on farmers' paddy fields in Beleke, West Lombok (Indonesia), which was part of a three years of research project started in 2018 [6]. The Split Plot design with three blocks was used to arrange the treatments consisting of two factors, namely: rice growing techniques consisting of T1= conventional, T2= aerobic irrigation system as the main plots and types of organic wastes consisting of four treatments: L0= no organic waste, L1= rice husk (RH), L2= rice husk ash (HA), and L3= combination of rice husk ash cattle manure (HM) as the sub-plots. The procedures applied in running this experiment are as described previously [12], while procedures for application of the organic wastes are also as described previously [13]. The red rice genotypes used were the G-4 amphibious line of red rice [2].

The observation variables were soil bulk density using core method [14], soil moisture at field capacity [14], red-rice plant height, number of tillers, leaves, panicles and filled grain per clump, dry straw weight, weight of 100 grains, and grain yield per clump. Data were analyzed with ANOVA and Tukey’s HSD at \( p=0.05 \) using CoStat Windows ver. 6.303.

3. Results and Discussion

In relation to soil physical properties, application of organic wastes showed a significant effect on soil bulk density and water content at field capacity, but techniques of growing rice only showed a significant effect on soil bulk density, i.e. lower in T2 (aerobic) than in T1 (conventional). However, there was a significant interaction effect on soil bulk density (Table 1). The pattern of interaction is presented in Figure 1.

Changing rice cultivation technique from conventional to aerobic irrigation system significantly reduced bulk density of the soil. The addition of organic waste, especially rice husk ash with cattle manure, can also reduce soil bulk density. This could occur because the function of organic matter in the soil is to stimulate the granulation process of soil particles and to prevent soil compaction. The formation of soil structure through the granulation process is followed by an increase in water holding capacity of the soil, as well as an increase in soil moisture content at field capacity. These all resulted in better availability of water for plants. This relates to the data in Table 1, showing significantly higher
field capacity water content in L3 than in L0. This could occur because rice husk ash in combination with cattle manure could increase the number of colloidal particles in the soil with high surface area [15].

Table 1. ANOVA results and effects of each factor on soil bulk density and soil moisture content at the field capacity.

| Treatments                        | Bulk density | Soil moisture content at field capacity |
|-----------------------------------|--------------|----------------------------------------|
| L0: no organic                    | 0.97bc       | 31.93c                                 |
| L1: rice husk (RH)                | 0.98ab       | 33.11b                                 |
| L2: husk ash (HA)                 | 1.00a        | 34.16a                                 |
| L3: husk ash + manure (HM)        | 0.96c        | 32.68b                                 |
| HSD0.05                           | 0.02         | 0.73                                  |
| T1: conventional                 | 1.03a        | 34.14a                                 |
| T2: aerobic rice                  | 0.93b        | 31.80a                                 |
| HSD0.05                           | 0.00         | 2.39                                  |

Techniques  s  n
Wastes  s  s
Interaction  s  n

Remarks: n= nonsignificant; s= significant; different lowercase letters indicate differences between treatments

![Figure 1](image_url)

The higher bulk density in the conventional rice soil (T1) than in the soil of the aerobic irrigation system (T2) could be due to differences in tillage operation. Intensive tillage, as was applied in conventional rice soil may damage the soil structure that can end up with the formation of soil compaction, thereby reducing the continuous pore space of the soil, as reported by Pires et al. [16] and Rusu et al. [17], that minimum or zero tillage will produce continuous pores in the topsoil layer. The significant interaction effect on soil bulk density in Fig. 1 indicates that the highest bulk density was in the conventional rice soil, especially those amended with rice husk ash mixed with cattle manure (T1L3), while the lowest value was in the rice soil under aerobic irrigation system, especially those amended with rice husk ash mixed with cattle manure (T2L3). This fact indicates that the soil bulk density was determined by the difference in tillage operation between the two rice growing techniques (T) rather than by the treatment of organic waste (L). No soil tillage was done in the aerobic irrigation system (T2), while under conventional technique intensive soil tillage was done, as what the farmers normally do for rice.

In relation to rice, organic wastes showed significant effects both on growth and yield variables, while between techniques of growing red-rice, the difference was significant only in DSW/clp, NP/clp,
NFG/clp and GY/clp, which are higher in aerobic than conventional red-rice, and PH (cm), which is higher in conventional than aerobic red rice (Table 2). In relation to organic wastes, red-rice growth and yield increased due to organic waste application, especially in L2 or L3. This is possible because in both treatments the growing environment was good, as indicated by a good water availability, which shows higher in field capacity water content than that of both control treatment (L0) and treatment of rice husk (L1). This improved condition was also supported by soil bulk density (Table 1), which decreased significantly in the treatment of organic waste, especially rice husk ash with manure (L3).

Table 2. Effect of organic waste and irrigation system on crop growth and yield of red rice.

| Treatment | PH (cm) | NT/clp | NL/clp | DSW/clp | NP/clp | NFG/clp | Wt-100 | GY/clp |
|-----------|---------|--------|--------|---------|--------|---------|--------|--------|
| L0: no organic | 72.47 b | 19.97 b | 79.20 c | 23.10 b | 16.17 b | 1038.17 c | 2.44 ab | 25.20 c |
| L1: rice husk | 73.79 b | 20.21 b | 79.92 c | 26.05 ab | 15.83 b | 1058.83 bc | 2.44 ab | 25.73 bc |
| L2: husk ash | 80.64 a | 22.67 a | 87.22 b | 30.45 a | 17.17 ab | 1169.83 ab | 2.42 b | 27.95 b |
| L3: ash+manure | 83.50 a | 23.11 a | 95.43 a | 28.35 ab | 18.33 a | 1230.83 a | 2.56 a | 31.58 a |
| HSD0.05 | 5.45 | 2.38 | 6.78 | 5.44 | 2.09 | 114.72 | 0.13 | 2.57 |

Techniques

| Wastes | s | s | s | s | n | s |

Interaction

Remark: PH = plant height (cm), NT/clp = number of tillers/clump, NL/clp = number of leaf/clump, DSW/clp = dry straw weight/clump, NP/clp = number of panicle per clump, NFG/clp= number of filled grain per clump, Wt-100 = weight of 100 grains; WtG/clp= weight of filled grain per clump; n = non-significant; s= significant at p-value = 0.05

The significant interaction on PH (Figure 2) and NL/clp (Figure 3) explains that there was an increase in both variables due to the addition of rice husk ash, either without or with manure. The T1L2 and T1L3 treatments produced a higher value than T1L0. The same pattern of increase also occurred in T2L2 and T2L3 treatments which were also higher than T2L0. Kiswondo [11] reported similar results, that rice husk ash at an application dose of 50 g/plant gave higher tomato growth and yields than the treatment without organic waste.

The interaction effects on dry straw weight (Figure 4) shows that the application of rice husk ash without (L2) or with manure (L3) in aerobic irrigation technique (T2) has better results than that of the same organic waste treatment of the conventional techniques (T1). In relation to the grain yield of red rice per clump (Figure 5), interaction effect indicated that conventional red rice did not seem to be
responsive to types of organic wastes while under aerobic irrigation systems, red rice was highly responsive to different types of organic wastes. The highest grain yield (37.78 g/clump) was obtained on red-rice in T2 (aerobic) amended with husk ash and cattle manure (L3), while the lowest grain yield (21.27 g/clump) was in conventional rice without application of organic waste (L0). On average, changing from conventional technique to aerobic irrigation system could increase red rice grain yield by 40.13%.

4. Conclusion
Changing rice cultivation technique from conventional to aerobic irrigation system significantly reduced soil bulk density, especially under application of rice husk ash together with cattle manure or without cattle manure. The highest red rice grain yield of 37.78 g/clump was on rice plants under aerobic irrigation technique combined with rice husk ash, whereas the lowest yield was under conventional rice without organic wastes, which was only 21.27 g/clump. On average, changing from conventional technique to aerobic irrigation system could increase red rice grain yield by 40.13%.

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