Soil chemical characteristics and yield of red rice under aerobic irrigation system as affected by intercropping with peanut and application of organic wastes on permanent raised-beds

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Abstract. Intercropping with peanuts was reported to increase yield of cereal crops. The objective of this study was to examine the effect of peanut-intercropping and organic waste application on some soil chemical characteristics and red-rice yield under aerobic irrigation systems. The experiment was conducted from May to August 2020 in West Lombok (Indonesia), under Split Plot design, testing two factors, namely intercropping (T1= monocropped rice; T2= rice+peanut intercropping) in the main plots, and organic waste application (L0= without organic waste, L1= application of rice husk, L2= rice husk ash, L3= rice husk ash and cattle manure) in the subplots. Results showed that intercropping did not affect soil chemical properties but it significantly increased number of panicles and filled-grains, 100 grain weight, and grain yield of red rice per clump (31.27 g/clump under monocrop and 41.50 g/clump under intercropping with peanut). In contrast, organic waste application significantly influenced soil chemical characteristics and red-rice yield (the highest yield of 43.52 g/clump under L3). The significant interaction between factors on 100 grain weight indicated that the highest weight (2.89 g) was on intercropped red-rice under L3 treatment and the lowest one (2.18 g) was on monocropped red-rice under L2 treatment.

1. Introduction

As a staple food, rice is one of the agricultural commodities that need attention both in quality and quantity of yield. Compared with the common type of rice, i.e. white rice, red rice is superior in nutritional and health values due to its anthocyanin content, and there are also various promising lines of red rice that are suitable for both upland or dry and flooded conditions of growing environments [1]. Although upland rice normally yields less than conventional paddy or flooded rice, cultivation of red-rice under irrigated aerobic system on raised-beds is more promising for more sustainability compared with growing rice under flooded conditions because rice can be intercropped with other crops such as peanut or soybean [2, 3, 4, 5]. Yield of rice under an aerobic irrigation system has been proven to increase grain yield compared with growing it under the conventional flooded system [6, 7]. Yield of non-rice food crops such as soybean was higher following rice in the aerobic irrigation system than following conventional rice crops [8, 9]. Soybean, which was direct-seeded following conventional rice crop yielded very low, but when it was inoculated with both Rhizobium bacteria in combination with mycorrhiza biofertilizer, its grain yield significantly increased [10]. In addition, rice grown on the
permanent bed system in vertisol land was found to be more efficient in using irrigation water than on the conventional rice system, with 45% more efficient in water use [11].

Inclusion of legume crops such as soybean and peanut to be intercropped with rice plants, in addition to increasing rice yield [2, 3, 4, 5], also has the potential to improve fertility of rice lands in the long-term due to the potential of legume crops to form symbiosis with *Rhizobium* bacteria and this symbiosis is capable of depositing fixed N into the soils [12, 13, 14]. However, without flooded conditions, growth of weeds and weed competition can be serious and in this study, weeding processes needed to be done very frequently. Under flooded conditions, weed competition on rice is less serious than under aerobic conditions but there are high potentials of nutrient losses, especially from nitrogen fertilizers due to volatilization of nitrogen and leaching loss of nitrogen and phosphates [15, 16]. However, the use of rice wastes such as rice husks spread on the soil surface was reported to be able to reduce weed growth [17]. Previous study showed that application of rice husk ash and combination of rice husk ash spread on the surface of raised-beds significantly increased red-rice yield [18]. This study aimed to examine the effect of intercropping with peanut and application of organic wastes on some soil chemical characteristics, growth and yield of red-rice under aerobic irrigation systems on permanent raised-beds.

2. **Materials and Method**

The field experiment was carried out in March to July in 2020, on a permanent raised-bed system established in May 2018 for a series of 3 year experiments, which were located in Beleke village of West Lombok Regency, Indonesia [2, 3]. The Split-Plot design was applied to arrange the experiment consisting of three blocks and two factors. The main plot treatment factor consisted of monocropped red rice on permanent raised-bed (PRB) (T1), and relay cropping red rice with peanut on PRB (T2). The sub plots were application of organic waste consisting of four treatments: without organic waste (L0), application of rice husk (L1), application of rice husk ash (L2), and combination of rice husk ash and cattle manure (L3). Therefore, in this study, there were 24 raised-beds each with a size of 1x3 m².

The materials used in this experiment other than those for the treatments included the G-4 promising lines of amphibious red rice [1], Hypoma-1 variety of peanut, Phonska and Urea fertilizers. The planting geometry of the red rice and peanut and the procedures applied to run the experiment have been published [2], but with different peanut varieties. The techniques of spreading the organic wastes on the raised-beds are as explained previously [18].

The measurement variables were soil pH in water (soil: water proportion of 1:2.5), soil available P (Bray-1 method), soil organic C (Walkley and Black method), soil total N (Kjeldahl method), rice dry straw weight, panicle number, %-unfilled grains, weight of 100 grains, and grain yield per clump. Data were analysed with ANOVA and Tukey’s HSD at p=0.05, using CoStat for Windows ver. 6.303.

3. **Results and Discussion**

The Summary of ANOVA results (Table 1) shows no significant different in soil chemical properties between the cropping system treatments, but they were significantly different among organic waste treatments, indicated by soil pH, soil organic-C, soil available P, and soil total N. In relation to crop growth and yield components, significant differences between cropping systems were observed on average growth rates of plant height, number of panicle per clump, number of filled panicle per clump, weight of 100 filled grains, and grain yield of red rice per clump. In contrast, the effect of organic waste treatments was significant on all red rice variables observed, except for the number of tillers per clump. However, the interaction effect was significant only on the average growth rates of plant height and weight of 100 filled grains of the red rice.

The soil chemical characteristics were not affected by cropping system treatments (T) indicated by available P, total N, soil pH, and organic-C (Table 2), which were measured on soil samples taken after harvest of the red rice. These results were possibly associated with higher nutrient uptake, especially N and available P, by rice plants in rice-peanut intercropping system (T2) resulting higher grain yield of
the intercropped (T2) than the monocropped red-rice (T1) (Table 3). However, among the organic waste treatments, Table 2 shows that soil available P was highest under application of a combination of rice husk ash and cattle manure (L3). This is highly likely due to higher soil nutrient, especially phosphorus, released to soil from the decomposition, especially of cattle manure. Similar figures also occurred on total soil nitrogen. Overall, the highest soil chemical characteristics tend to consistently occur under combination of rice husk ash and cattle manure. This undoubtedly occurred because rice husk ash will increase the colloidal soil particles together with the enhancement of the nutrients which are released from the decomposition of the cattle manure. Increase in soil pH under addition of organic waste possibly due to release of basic cations that can bind the hydrogen ions which may result in increased soil pH.

Table 1. The results of ANOVA for all variables.

| Variables                  | Treatments | Cropping system (T) | Organic waste (L) | Interaction (T*L) |
|----------------------------|------------|---------------------|-------------------|------------------|
| Soil pH in water           | n          | s                   | n                 |
| Soil organic-C (Walkley and Back) % | n          | s                   | n                 |
| Soil available P (Bray-1) (ppm) | n          | s                   | n                 |
| Soil total N (Kjeldahl) (%) | n          | s                   | n                 |
| AGR of plant height (cm/day) | s          | s                   | s                 |
| Number of tillers per clump | n          | n                   | n                 |
| Dry straw weight per clump (g) | n          | s                   | n                 |
| Number of panicle per clump | s          | s                   | s                 |
| Number of filled grains per clump | s          | s                   | n                 |
| 100 grain weight (g)        | s          | s                   | s                 |
| Grain yield (g/clump)       | s          | s                   | n                 |

Remarks: n= nonsignificant; s= significant

Table 2. Mean of available P, Total of N, soil pH, and organic-C under different cropping system and addition of organic waste.

| Treatments                  | Available-P (ppm) | Total-N (%) | Soil pH | Organic-C (%) |
|-----------------------------|-------------------|-------------|---------|---------------|
| T1= monocrop rice           | 7.64              | 0.18        | 6.45    | 1.70          |
| T2= rice+peanut intercropping | 8.87              | 0.20        | 6.37    | 1.75          |
| HSD0.05                     |                   |             | HSD0.05 |               |
| L0= without waste           | 6.53 c            | 0.15 c      | 5.80 c  | 1.34 d        |
| L1= rice husks              | 7.84 b            | 0.19 b      | 6.72 ab | 1.77 b        |
| L2= rice husk ash           | 8.39 b            | 0.19 b      | 6.09 bc | 1.51 c        |
| L3= rice husk ash + manure  | 10.26 a           | 0.23 a      | 7.03 a  | 2.28 a        |
| HSD 0.05                    | 0.74              | 0.016       | 0.53    | 0.15          |

There was no significant difference in dry straw weight per clump of red rice between different cropping systems observed (Table 3). However, other variables such as number of red rice tillers and filled grains per clump were significantly higher in rice-peanut intercropping, which indicated that relay-planting peanuts between red-rice double-rows resulted in better growth and rates of seed-filling process of red rice. This was also supported by weight of 100 filled grains (Figure 2), which was higher in red rice relay-planted with peanut (T2) compared to that of monocropped red rice (T1). As a consequence, it is then logical that red rice yield was higher in peanut-intercropped than monocropped red rice (Table 3). Previous reports also showed that when intercropped with legumes, cereal crops can have higher rates of nutrient uptake and/or higher grain yield of the cereal crops compared with under monocropped cereals [19, 20, 21, 22]. Previous studies also reported similar results regarding the growth and yield increase of rice under intercropping with legumes such as soybean and peanut [2, 3, 5, 18]. Sweet corn
intercropped with peanuts was reported to be greener with a higher number of green leaves at harvest compared with monocropped sweet corn plants [22].

Table 3. Mean of dry straw weight of red rice (g/clump), number of tillers, and filled grains weight (g/clump) under different cropping systems and organic wastes application.

| Treatments                      | Dry straw weight (g/clump) | Number of tillers per clump | Number of filled grains per clump | Grain yield (g/clump) |
|--------------------------------|----------------------------|----------------------------|----------------------------------|-----------------------|
| T1= monocrop rice              | 34.15 a                    | 21.00 b                    | 1339.41 b                        | 31.27 b               |
| T2= rice+peanut intercropping  | 33.79 a                    | 25.25 a                    | 1681.41 a                        | 41.50 a               |
| HSD0.05                        |                           | 3.10                       | 135.80                           |                       |
| L0= without waste              | 29.60 b                    | 21.66 b                    | 1399.50 b                        | 33.33 b               |
| L1= rice husks                 | 28.59 b                    | 21.83 b                    | 1442.83 ab                       | 34.62 b               |
| L2= rice husk ash              | 38.48 a                    | 23.66 ab                   | 1483.30 ab                       | 35.26 b               |
| L3= rice husk ash + manure     | 39.22 a                    | 25.33 a                    | 1590.00 a                        | 43.52 b               |
| HSD0.05                        |                           | 4.08                       | 1.53                             | 126.40                |

Application of organic waste in the form of combination of rice husk ash and cattle manure (L3) tended to result in higher red rice growth and yield compared with other types of organic wastes as well as the control treatment, although it was not significantly different from that of the application of rice husk alone (L2), especially on the dry straw weight per clump and number of tillers per clump (Table 3). This finding suggests that in order to get higher red rice yield, rice husk should be applied in the form of ash combined with cattle manure. The cattle manure will act as nutrient sources and rice husk ash will increase soil particles in the colloids form, and as the soil colloids increase, nutrient adsorption in the soil could increase, resulting in higher nutrient availability to the plants [23].

There was also significant interaction although it was only on AGR of plant height (Figure 1) and weight of 100 filled grains (Figure 2). Under monocropped aerobic irrigated red rice (T1), application of different types of organic wastes tended to result in similar growth rate of plant height, while under rice-peanut intercropping (T2) the application of different types of organic wastes resulted in higher growth rates of plant height compared with under monocropped red rice. The pattern of interaction effects on the weight of 100 grains (Figure 1) was slightly different from that on the AGR of plant height (Figure 2), in which the tendency of having the highest weight of 100 grains was in red rice amended with a combination of rice husk ash and cattle manure. However, both the AGR and weight of 100 grains were higher in rice-peanut intercropping (T2) than in monocropped red-rice (T1), and this could be due to a better supply of nitrogen as a result of the activity of *Rhizobium* bacteria in fixing nitrogen in the peanut’s root nodules under T2 treatment [12, 13, 14, 20].

![Figure 1](image_url). Interaction effect on average growth rate (AGR) of plant height of red rice.
4. Conclusion
It can be concluded that one season of the cropping system did not affect the soil chemical characteristic, but the characteristics could be affected by the application of organic waste. Application of organic waste in the form of rice husk ash combined with cattle manure resulted in the highest concentration of soil available P, total-N, organic-C, and slight increase in soil pH. Additive intercropping of red rice with peanuts resulted in higher yield of red rice. This research is required to be continued by taking into account a long term effect of intercropping rice with peanut on the soil properties.

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