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# Yield of Two Red Rice Genotypes between Flooded and Aerobic Rice Systems Intercropped With Soybean

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***Abstract:*** *This study aims to determine the effect of aerobic rice system, either with or without organic fertilization and intercropping with soybean, on growth and yield of two genotypes of red rice. The experiment was arranged in Completely Randomized Design testing three treatment factors: rice cultivation techniques (T1= conventional, T2= aerobic rice intercropped with soybean, T3= aerobic rice without intercropping); organic fertilization (B0= without, B1= with organic fertilization using "Bokashi"); red rice genotypes (V1= Inpago Unram 1, V2= Amp-G9), with three replications. The results indicated that the interaction was significant only between cultivation techniques and organic fertilization on plant height at 8 weeks after planting (WAP) and leaf number at 5 WAP. However, rice cultivation techniques significantly affected almost all observation variables, whereas organic fertilization significantly affected only plant height at 8 WAP. In relation to yield, the aerobic rice system without intercropping with soybean (T3) yielded significantly the highest rice grain weight per clump (40.32 g) compared with the aerobic system intercropped with soybean (32.68 g) and the conventional technique (22.67 g). Based on "Best Subsets Regression", growth rate of tiller number (which was highest in T3), contributed the highest to rice grain yield (55.8%), and panicle length (59.6%).*

***Keywords:*** *Aerobic rice system, intercropping, organic fertilization, red rice, soybean*

## I. Introduction

Rice (*Oryza sativa* L.) is the most important food crop in Indonesia because most of Indonesia's population depends on rice as everyday staple food. According to Nguyen (2010), rice is in fact also the staple food for half the world's population. Although Indonesia is the third largest rice producing country after China and India (Kompas, 02-09-2015), Indonesia still needs to import rice each year from several countries (Yudha, 2016).

Lately, in addition to the quantity, Indonesian people have started to think about the nutritional and health values of the rice to be consumed. This is evident from the red rice trade in the market or supermarket, in which red rice is very quickly sold out even though the price of red rice can be twice or more than the price of good quality white rice. This happens because most people have realized the health functions of red rice. The red color in the red rice is caused by the presence of anthocyanins, which are members of phenolic compounds (Fasahat et al., 2012), and those phenolic compounds produce high antioxidant activities in red rice (Fasahat et al., 2012; Anggraini et al., 2015). From some cultivars of red and black rice in West Sumatra, Anggraini et al. (2015) reported that red rice cultivar from South Solok is the best, with a high antioxidant activity, i.e. up to 54.2% at a concentration of 0.25 mg/ml, with a total polyphenol content of 31.3 mg/ml, and 7.9% protein.

However, most of the cultivars and promising lines of red rice in Indonesia are upland cultivars with relatively low productivity. Therefore, it is necessary to improve the productivity of red rice cultivars, either through breeding or improved rice cultivation techniques. Through cross breeding and selection of rice plants, initiated by senior lecturers of the Faculty of Agriculture, University of Mataram (Unram), a new upland red rice cultivar called "Inpago Unram 1" and various promising lines of upland red rice have been produced. However, some promising lines of the upland red rice, after having been tested in wetlands (under flooded conditions), also produced relatively high grain yields, so they are considered as amphibious red rice lines, although some generated lines of the red rice are still better if grown as upland rice (Aryana and Wangiyana, 2016).

With improvements in techniques of rice cultivation, in addition to the conventional (flooded) technique of growing rice, which has been practiced since ancient time, there are newer techniques of rice cultivation which result in higher grain yields but save water. They are SRI technique (Uphoff, 2003) and aerobic rice system (ARS) (Prasad, 2011). By practicing the SRI (System of Rice Intensification) technique for six consecutive years on his farm, a farmer in Madagascar was reported to achieve 2.74 tons of rice grain yield from an area of 13 acres (equivalent to 21 t/ha), while with the same variety cultivated under conventional techniques practiced in adjacent plots, the rice grain yield obtained was only on average of 2.6 t/ha (Uphoff, 2003). With SRI technique, rice is irrigated intermittently between thin flooded and dry conditions with flooding intervals of at least one week during the vegetative phase, but it is thin flooded with irrigation water during the reproductive phase (Uphoff, 2003). In contrast, in aerobic rice systems, rice is grown without flooding and without puddling the soil during land preparation for planting rice (Prasad, 2011).

This article reports growth and yield of two selected genotypes of upland red rice to show that aerobic rice systems are better than conventional techniques of rice cultivation.

## II. Materials And Methods

**Design of the Experiment**

The experiment in this research was conducted in a plastic house in the experimental garden of the Faculty of Agriculture, University of Mataram (Unram), located in Nyur Lembang village, Narmada (West Lombok, Indonesia), from May to September, 2015. The experiment was arranged according to the Completely Randomized Design, testing three factors, namely: (1) Rice cultivation techniques (T) with 3 treatments [T1= conventional (flooded system), by transplanting seedlings of 25 days old; T2= aerobic rice system (ARS) intercropped (or grown) with soybean plants; and T3= aerobic rice system without intercropping with soybean]; (2). Rice genotypes or varieties (V), consisting of 2 red rice genotypes [V1= “Inpago Unram 1” (an upland red rice variety) and V2= “Amp-G9”, a promising amphibious red rice line (a red rice genotype developed for dryland but also well-adapted to flooded conditions)]; and Organic fertilization with “Bokashi” (B), consisting of 2 treatments [B0= without organic fertilization (the crops only fertilized with N, P, K fertilizers using Urea (45% N), SP-36 (36% $P_2O_5$), and KCl (60% $K_2O$) at the recommended doses of 300 kg/ha Urea, 150 kg/ha SP-36, and 150 kg/ha KCl), and B1= fertilization with “Bokashi” compost (EM-4 fermented compost of cattle manure) at a dose of 20 t/ha, plus half the recommended dose of the N, P, K fertilizers)]. By combining these three treatment factors there were 12 treatment combinations, each of which was made in 3 replications.

**Implementation of the Experiment**

Rice plants were grown in plastic pots filled with 6 kg air dried entisol soil plus 400 g rhizosphere of soybean stubble taken from the experimental garden during dry season 2015. The diameter of the surface of soil in the pots was 26 cm with a depth of 16 cm. The complete procedures for preparing growing media and planting the rice plants in the pots as well as crop maintenance activities for the rice and soybean plants during the experiment are as explained in Dulur et al. (2015b).

**Observation Variables and Data Analysis**

Data were obtained from measurement of growth variables and yield components, followed by calculation of average growth rates (AGR) of plant height, leaf number (i.e. number of leaves that are still green), and tiller number, measured every 7 days starting at 7 days after planting (DAP). Yield components were weight of dry (14% water content) filled grains per clump for rice and dry seeds per clump for soybean in the intercropped pots, average panicle length and weight of 100 dry grains for rice. Data were analyzed using analysis of variance (ANOVA) and Honestly Significant Difference test (Tukey’s HSD) at 5% level of significance, using the statistical software “CoStat for Windows ver. 6.303”. Regression analysis and “Best Subset Regression” were also performed to determine the magnitude of relationship between observation variables, using the statistical software “Minitab for Windows Release 13”.

## III. Results And Discussion

Based on the ANOVA results summarized in Table 1, interaction effects are significant only between rice cultivation techniques (T) and “Bokashi” organic fertilization (B) but only on plant height at 8 WAP and leaf number per clump at 5 WAP. Among the three treatment factors, rice cultivation technique (T) is the most dominant factor influencing almost all observation variables except leaf number at 6 WAP and AGR of plant height, while organic fertilization with “Bokashi” only influences plant height at 8 WAP. Both red rice genotypes tested were also generally not significantly different in terms of their growth and grain yield, except in plant height (at 7 & 8 WAP), leaf number at 5 WAP, and weight of 100 grains.

The interaction effects between rice cultivation techniques and “Bokashi” fertilization shown in Fig. 1 indicate that plant height at 8 WAP and leaf number at 5 WAP are on averages significantly higher on red rice plants grown on the conventional than on aerobic systems, either with or without intercropping with soybean. This can happen because at the planting time, rice seedlings planted in the conventional technique were in the form of 25-day-old seedlings while on the aerobic systems they were planted as rice sprouts. It can also be seen from Fig. 1, that average height of rice plants in the conventional technique was higher in pots unfertilized with “Bokashi” compared with those in pots fertilized with “Bokashi” organic fertilizer, while those grown on the aerobic systems, either with or without intercropping with soybean, there were no differences in rice plant height. In the contrary, leaf number of the rice plants growing on the aerobic systems was higher in the pots fertilized with "Bokashi" fertilizer, both for rice intercropped with soybean (T2) and without intercropping with soybean (T3), especially at 7 and 8 WAP (Fig. 2).

**Table 1.** Summary of ANOVA results for plant height (at 7 & 8 WAP), leaf number per clump (at 5, 6, 7 & 8 WAP), tiller number per clump (at 6, 7 & 8 WAP), and average growth rates of plant height, leaf number and tiller number, as well as weight of dry filled grains per clump

| **Observation variables** | **Main effects** | | | **Interaction effects** | | | |
|---|---|---|---|---|---|---|---|
| | Tech | Var | B | TxV | TxB | VxB | TxVxB |
| Plant height at 7 WAP | ** | ** | ns | ns | ns | ns | ns |
| Plant height at 8 WAP | *** | *** | * | ns | * | ns | ns |
| Leaf number per clump at 5 WAP | *** | * | ns | ns | * | ns | ns |
| Leaf number per clump at 6 WAP | ns | ns | ns | ns | ns | ns | ns |
| Leaf number per clump at 7 WAP | * | ns | ns | ns | ns | ns | ns |
| Leaf number per clump at 8 WAP | ** | ns | ns | ns | ns | ns | ns |
| Tiller number per clump at 6 WAP | ** | ns | ns | ns | ns | ns | ns |
| Tiller number per clump at 7 WAP | *** | ns | ns | ns | ns | ns | ns |
| Tiller number per clump at 8 WAP | *** | ns | ns | ns | ns | ns | ns |
| Growth rate of plant height | ns | ns | ns | ns | ns | ns | ns |
| Growth rate of leaf number | *** | ns | ns | ns | ns | ns | ns |
| Growth rate of tiller number | *** | ns | ns | ns | ns | ns | ns |
| Weight of dry filled grains per clump | *** | ns | ns | ns | ns | ns | ns |
| Average panicle length | *** | ns | ns | ns | ns | ns | ns |
| Weight of 100 dry filled grains | ** | * | ns | ns | ns | ns | ns |

Remarks: ns = non-significant ($p>=0.05$); *, **, *** = significant at $p<0.05$; $p<0.01$; $p<0.001$ respectively; WAP = weeks after planting; Treatments: Tech or T = rice cultivation techniques; Var or V = red rice variety or genotype; B = "Bokashi" fertilization

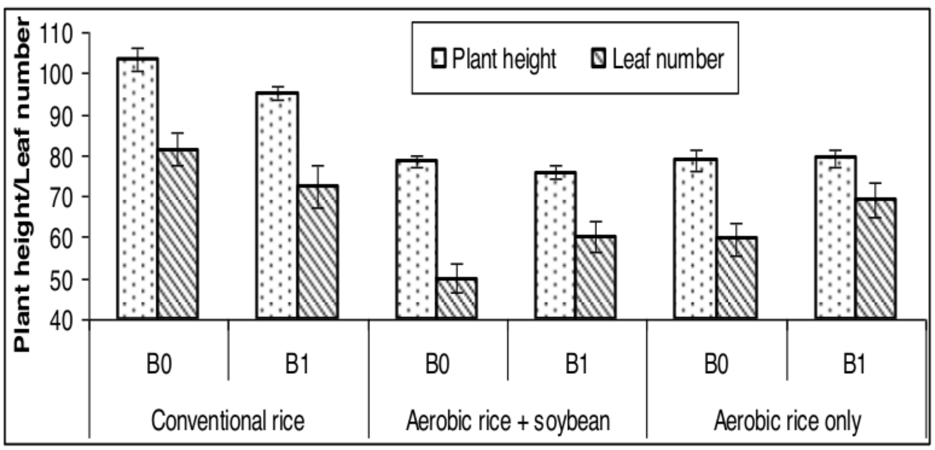


**Fig. 1.** Averages (Mean ± SE) of red rice plant height (cm) at 8 WAP or leaf number at 5 WAP for each combination of cultivation technique and "Bokashi" organic fertilization (B0 vs B1)

If seen from the increase in leaf number from the age of 5 to 8 WAP, it can be seen from Fig. 2 that the development of leaf number was higher on rice under aerobic cultivation techniques, especially those without intercropping with soybean but organic fertilized with "Bokashi" compost, and leaf numbers were still increasing after the age of 7 WAP. On the other hand, leaf numbers of rice plants (i.e. number of green leaves at the observation time) on the conventional technique were already decreasing after the age of 6 WAP.

The higher averages of leaf number of red rice plants under aerobic systems than under conventional techniques during the vegetative phase (up to the age of 8 WAP) would lead to higher leaf area index (ILD) of the rice plants growing under aerobic systems. This would result in the higher rates of canopy photosynthesis of rice plants on the aerobic systems than on the conventional techniques due to the significantly positive relationship between ILD and canopy photosynthesis of rice plants (Peng, 2000), and these differences would also result in the differences in tiller number, which were on averages higher on the aerobic rice systems, especially on the rice plants grown without intercropping with soybean (Table 2).

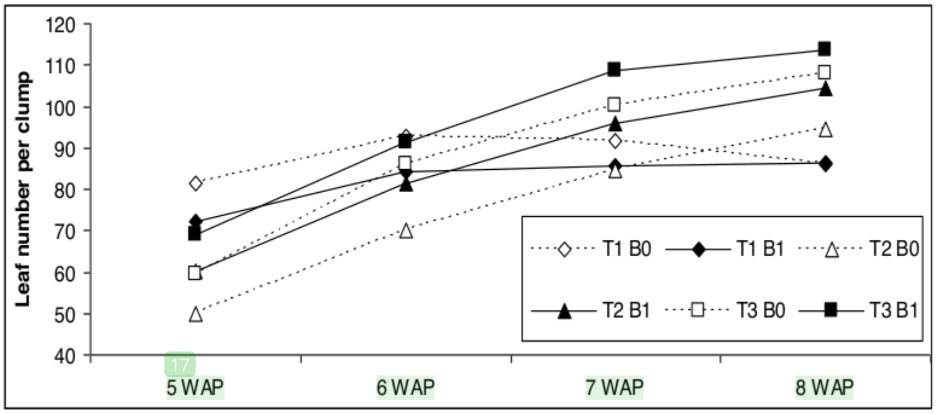


**Fig. 2.** Development of average leaf number per clump on red rice plants at 5 to 8 WAP on each combination of rice cultivation techniques and organic fertilization with "Bokashi" compost (B0 vs B1)

**Table 2.** Averages of rice leaf number per clump at 6, 7 and 8 WAP, average growth rate (AGR) of leaf number, and weight of dry filled grains per clump for each level of treatment factor

| Treatments | Average tiller number per clump | | | | | | AGR of tiller number | | Grain yield (g/clump) | | Panicle length (cm) | | 100 grain weight (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 WAP | | 7 WAP | | 8 WAP | | | | | | | | | |
| T1= conventional | 24.08 | a | 24.25 | b | 21.50 | c | 1.76 | c | 22.67 | c | 16.58 | c | 2.77 | a [1)] |
| T2= Aerobic+soybean | 19.67 | b | 23.58 | b | 28.42 | b | 4.49 | b | 32.68 | b | 19.12 | b | 1.75 | c |
| T3= Aerobic rice only | 27.08 | a | 34.42 | a | 37.25 | a | 6.47 | a | 40.32 | a | 20.19 | a | 2.21 | b |
| HSD 5% | 4.34 | | 4.58 | | 5.43 | | 1.12 | | 6.88 | | 0.93 | | 0.16 | |
| V1= Inpago Unram 1 | 23.39 | a | 28.06 | a | 29.17 | a | 4.43 | a | 32.63 | a | 18.84 | a | 2.31 | a |
| V2= Amp-G9 line | 23.83 | a | 26.78 | a | 28.94 | a | 4.06 | a | 31.16 | a | 18.42 | a | 2.18 | b |
| HSD 5% | 2.93 | | 3.09 | | 3.66 | | 0.75 | | 4.64 | | 0.63 | | 0.11 | |
| B0= no "Bokashi" | 23.61 | a | 27.67 | a | 28.72 | a | 4.21 | a | 32.85 | a | 18.69 | a | 2.24 | a |
| B1= with "Bokashi" | 23.61 | a | 27.17 | a | 29.39 | a | 4.27 | a | 30.94 | a | 18.56 | a | 2.24 | a |
| HSD 5% | 2.93 | | 3.09 | | 3.66 | | 0.75 | | 4.64 | | 0.63 | | 0.11 | |

[1)] Mean values in each column followed by the same letters are not significantly different between levels of each treatment factor, based on its Tukey's HSD value at 5% level of significant

Therefore, it is clear from Table 2 that the lowest number of tillers per clump was on the rice plants grown under the conventional technique (T1), i.e. under flooded conditions. In the procedures of cultivating paddy rice crops, rice plants should be flooded with standing water of up to 10 cm from the age of 35 to 50 weeks after transplanting to prevent late formation of tillers (Deptan, 1977). This means that the aerobic rice system can increase tiller number, and consequently leaf number, because rice plants are grown without flooded conditions. In terms of irrigation technique, aerobic rice system is similar to SRI technique during the vegetative phase, which avoids long flooded conditions so that tiller numbers are also high on SRI paddy cultivation techniques, which lead to higher grain yield compared with on the conventional techniques (Uphoff, 2003).

It is also evident from Table 2 that grain yield is much higher on red rice plants grown on aerobic system without intercropping with soybean (T3) and significantly different from that on the conventional techniques (T1), i.e. 40.32 g/clump on T3 compared with only 22.67 g/clump on T1. The average length of panicles also shows a similar trend, with the highest length is on T3. However, the weight of 100 filled grains is highest on rice plants grown on the conventional techniques, and lowest on those grown on the aerobic system intercropped with soybean (Table 2). This is logical because rice plants on the conventional technique had the lowest number of tillers so that more assimilates could be allocated to each grain, while those growing on the aerobic system intercropped with soybean, although had more tillers, the resources in the soil were shared by rice and soybean plants growing together in the pots with the same amount of resources.

Based on the results of "Best Subsets Regression" it is also evident that among the growth variables measured, the contribution of daily growth rate of tiller number (X) was the highest and significant, reaching up to 55.8% (with $R^2 = 0.558$; p-value <0.001), to rice grain yield (Y), with a regression equation $Y = 18.2 + 3.24 X$. It also contributed the highest to the average length of panicles, reaching up to 59.6% (with $R^2 = 0.0596$ p-value <0.001), with a regression equation $Y = 16.03 + 0.6 X$, and the average growth rate of tiller number in fact was highest on rice plants grown on the aerobic rice system, especially those without intercropping with soybean (T3) (Table 2).

In relation to grain yield, with multiple regression analysis using four X-variables of rice growth data, then the combination of X-variables contributing the highest, and all significant, to rice grain yield per clump were plant height at 5 WAP ($X_1$), leaf number at 8 WAP ($X_2$), tiller number at 6 WAP ($X_3$), and the growth rate of tiller number ($X_4$), which together contributed 66.4% to rice grain yield per clump (Y), with a regression equation $Y = 60.31 - 0495\ X_1 - 12{:}23\ X_2 + 0.67\ X_3 + 3015\ X_4$ ($R^2 = 0.664$; p-value $<0.001$), and the growth rate of tiller number ($X_4$) gives the highest coefficient, and its contribution is highly significant (p-value $<0.01$).

It should also be noted that dry grain yield of soybean (Anjasmoro variety) was about normal even though soybean grew together with rice plants in the pots with the same resources as in the pots of aerobic system without intercropping with soybean, with average soybean grain yields ranging from 5.90 to 8.70 g/clump on pots without "Bokashi" fertilization, and from 11.27 to 14.40 g/clump on pots with "Bokashi" fertilization (Table 3). With an assumption of the growing space of 20 cm x 20 cm, then the highest mean of soybean grain yield was 3.6 t/ha on organic fertilized pots, and the lowest mean of 1.48 t/ha on pots receiving no organic fertilizer.

**Table 3.** Averages (Mean ± SE) of rice and soybean dry grain yield (g/clump) for each treatment combination of rice cultivation techniques, rice genotypes, and "Bokashi" fertilization

| Rice genotypes | Bokashi fertilization | Average grain yield of rice and soybean (g/clump) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Conventional rice | | Aerobic rice system intercropped with soybean | | | | Aerobic rice without soybean | |
| | | Rice | SE | Rice | SE | Soybean | SE | Rice | SE [1)] |
| V1= Amp G9 | B0= 0 t/ha | 22.71 | 3.90 | 32.57 | 1.07 | 5.90 | 0.45 | 45.63 | 3.70 |
| | B1= 20 t/ha | 25.05 | 3.38 | 31.03 | 7.98 | 14.40 | 2.80 | 38.77 | 1.88 |
| V2= Inpago Unram-1 | B0= 0 t/ha | 20.11 | 4.37 | 34.73 | 5.15 | 8.70 | 1.85 | 41.34 | 3.75 |
| | B1= 20 t/ha | 22.81 | 2.35 | 32.40 | 0.91 | 11.27 | 2.37 | 35.56 | 2.69 |

[1)] SE = standard error calculated from three replications of each treatment combination

In addition to higher grain yield of the upland red rice genotypes on an aerobic system as has been proven in this study (Table 2), aerobic rice systems may also have other superiorities compared with the conventional technique of growing rice because of the absence of flooded conditions in the aerobic rice systems. When there is no flooding in growing rice crop, then rice can be intercropped with other non-rice crops, especially legume crops, to facilitate $N_2$ fixation by legume crops that can contribute to the nitrogen nutrition of rice, as has been reported by Chu *et al*. (2004) from their experiment on intercropping rice with peanut. In addition rice grain yield, the aerobic rice systems intercropped with soybean in this study also produced soybean grain yield (Table 3).

Based on the results of this study, it is clear that aerobic rice systems (ARS) resulted in higher growth of those upland red rice genotypes, especially of leaf number and tiller number, which contributed the highest to grain yield of the red rice. Average grain yield of those red rice genotypes was also the highest on aerobic rice system without soybean (T3), which was significantly higher than that of rice on the conventional technique of growing rice (T1), i.e. on average of 40.32 g/clump on T3 compared with only 22.67 g/clump on T1. The aerobic rice system in which red rice plants were intercropped with soybean plants (T2) also resulted in significantly higher rice grain yield (32.68 g/clump) than those on the conventional technique (Table 2). Rice grain yield in the T2 treatment was lower than that of T3 treatment, but the T2 treatment also produced relatively high soybean grain yield, especially those fertilized with "Bokashi" organic fertilizer (Table 3).

## IV. Conclusion

Looking at the higher tiller number and rice grain yield per clump under aerobic rice systems (ARS), and/or additional soybean grain yield on the ARS intercropped with soybean, compared with the conventional technique, it is then necessary to develop some easy-to-practice ARS technologies that can be quickly adopted by the farmers normally practicing conventional techniques of growing rice. If such rice cultivation technologies that produce more grain yields are widely adopted by the farmers then improvement in rice production both nationally and globally will be easily achieved in a sustainable way due to inclusion of legume crops in the production systems.

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