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Growth of Several Amphibious Red Rice Lines between Conventional and Aerobic Systems Intercropped with Soybean

Ni Wayan Dwiani Dulur, Nihla Farida, A. Wiresyamsi, W. Wangiyana*

Faculty of Agriculture, University of Mataram (Unram) Jln. Majapahit No. 62, Mataram, NTB, Indonesia, 83125

****Coresponding author email:*** w.wangiyana@unram.ac.id

ABSTRACT: This study aims to determine the influence of rice cultivation techniques of aerobic systems, with or without intercropping with soybean plants, on growth of various amphibious red rice lines. The experiment was arranged in Completely Randomized Design, testing 3 treatment factors, i.e. red rice lines, rice cultivation techniques, and application of Bokashi (EM-4 fermented cattle manure). Data were analyzed using analysis of variance (ANOVA), followed by Honestly Significant Difference test at 5% significance level. The results indicated that there was no significant interaction between treatment factors except between rice cultivation techniques and varieties (rice lines). In addition to the varieties, rice cultivation techniques also had significant effects on most observation variables. Conventional rice cultivation techniques produce taller rice plants than the aerobic systems, whereas the aerobic systems resulted in higher number of leaves and tillers compared with the conventional techniques. Response of the rice crop to compost application was also better in the aerobic systems compared with in the conventional technique.
Keywords: amphibious, red rice, aerobic, soybean, intercropping

INTRODUCTION

The increasing rate of land use conversion of from the relatively flat irrigated fields into residential areas, shops and offices, which generally occurs around the cities in Indonesia, has gradually reduced the highly potential area for growing rice (Rahmadi, 12-08-2013), while Indonesia is still importing rice for food security (Witular, 25-09-2015). These facts coupled with the ever-increasing number of people, who mostly use rice as the main staple food, will continue to make food security getting difficult to be achieved. The getting limited area of irrigated fields due to conversion to the use for non-paddy fields, coupled with the increasing number of population could increase rice imports by Indonesia.

In order to reduce rice imports, the domestic production should be increased. One way to increase production is to increase productivity in addition to the expansion of planting area. According to the statistics data on food crops in Indonesia (BPS, 2011), from 2010 to 2011, in addition to a decline in harvested area there was also a decline in the average productivity, i.e. from 5.015 t/ha to 4.98 t/ha, bringing the total production decreased. To improve productivity, a technological breakthrough of rice production needs to be produced by finding new innovations, which should also widely practiced by the farmers; so they do not only practice conventional techniques of rice cultivation, in which rice is grown in flooded conditions, as what they normally applied.

By applying the conventional rice cultivation techniques, it has been demonstrated in Madagascar that rice productivity is constantly low. In fact, there has been a declining tendency of rice productivity from year to year unless high external inorganic inputs are applied. With the SRI (System of Rice Intensification) technique of growing rice, in which intermittent irrigation is applied during vegetative phase followed with thin flooding during reproductive phase, and the use of compost, it has been demonstrated in Madagascar, that rice productivity can be improved. A farmer, after applying the SRI technique for 6 years, was reported to obtain rice grain yield of 2.74 tons on an area of 0.13 ha (equivalent to 21 t/ha), while using the conventional techniques in the adjacent plots, the farmers could only obtain rice grain yield of an average of 2, 6 t/ha (Uphoff, 2002).

In addition to the SRI technique, aerobic system of rice cultivation techniques has been developed, in which the rice is grown under non-flooded, non-puddled and non-saturated soil condition (Prasad, 2011). Growing rice on a permanent raised-bed without puddling process, with irrigation water supplied through the furrows below the bed, can also provide aerobic or semi-aerobic conditions to the rice plants. By setting lower level of irrigation water in the furrows in the raised-bed system, aerobic conditions can be obtained in the top parts of the raised-beds (Dulur et al., 2012). Therefore, it is possible to grow non-rice crops, such as legume crops, together with rice plants in an intercropping system. There could be some advantages of growing legume crops in intercropping with rice in an aerobic rice system (ARS) because legume crops are capable of fixing nitrogen-free. In addition, legumes are also generally very responsive to symbiosis with arbuscular mycorrhizal fungi (AMF), and some even have a relatively high level of dependency on symbiosis with AMF (Thompson, 1991; Anderson and Ingram, 1993). In an intercropping cropping system, there are great opportunities for the transfer of nutrients between the intercropped plants through hyphal bridge, i.e. the AMF hyphae infecting roots of two adjacent intercropped plants (Smith and Read, 2008).

This study aimed to determine the effect of aerobic rice system and aerobic rice intercropped with soybean plants on growth of several amphibious red rice lines, compared with conventional rice systems, in which rice plants were grown in flooded conditions.

MATERIALS AND METHODS

Design of the experiment

In this research, an experimental method was applied by conducting the experiment in a plastic house of the Faculty of Agriculture, University of Mataram, from May to September, 2015. The experiment was arranged according to Completely Randomized Design, with 3 treatment factors, namely:

Rice Cultivation Techniques (T) with 3 treatment levels, namely:
Conventional (flooded system), by transplanting seedlings of 25 days age (T1).
Aerobic rice system grown with soybean (T2)
Aerobic rice system without soybean (T3)
Rice varieties (V), consisting of 4 amphibious red rice lines, namely: Amp G2, Amp G4, Amp G9 and Amp G10.

Organic fertilizers (O), with 2 levels of treatment:
Without organic fertilizer (only with N, P, K fertilizers using Urea, SP-36 and KCl at the recommended doses)
With Bokashi compost (EM-4 fermented compost of cattle manure) at a dose of 20 t/ha, plus half dose of the N, P, K fertilizers)

By combining these three factors there were 24 treatment combinations of, each of which was made in 3 replications.

Implementation of the experiment

The growing media used to fill the pots, each with 6 kg of air-dried soil, was taken from the topsoil of a paddock in the Narmada experimental garden belonging to the Faculty of Agriculture, University of Mataram (Unram). When the topsoil was taken, the paddock, classified as an entisol soil type, was in dry condition after harvest of soybean plants. Pots for the aerobic rice system, before being filled with the soil, were punched (4 holes circumference) of the side at the position of 2 cm above the base of the pot. After filling with the air-dried soil, the pots were also filled (around the planting hole in the center surface of the pot) with 400 g of rhizosphere soil freshly taken from rhizosphere of a soybean stubble (one stubble for one pot), after being sieved with 2 mm opening sieve, with a hope that this rhizosphere soil contained *Rhizobium* bacteria and propagules of arbuscular mycorrhizal fungi (AMF) since roots of the soybean stubbles contained *Rhizobium* nodules. After filling the pots with the two types of soil, two days before planting, the growing media in the pots were fertilized with basalt fertilizers using 1/3 dose of urea plus all doses of SP-36 and KCl fertilizers, and the Bokashi compost according the treatments of organic fertilization. The compost was inserted into the planting hole in the center of the growing media at the depth of 5-15 cm below the soil surface in the pot. For the conventional technique, just before applying the basalt fertilizers, the soil in the pots was flooded and puddle until it reached a condition with thin layer of stagnant water on the top of the soil in the pots, and left at this condition until transplanting time. At planting, the aerobic pots were planted with pre-germinated rice seeds, while the conventional pots were transplanted with rice seedlings of 25 old taken from a wet nursery. Soybeans in the aerobic intercropping pots were seeded by dibbling it about 5 cm beside the rice planting hole at 10 days after planting the rice pre-germinated seeds. Supplementary fertilization for rice was done at the age of 25 and 50 days after planting for aerobic technique and at the age of 21 and 42 days after transplanting for conventional techniques, each with 1/3 dose of urea. Watering for aerobic techniques was done using sub-irrigation by placing the pots in a plastic basin filled with water in such a way so that the pots were soaked with water maintained 5-10 cm high in the basin. For the conventional techniques, soil in pots was flooded by maintaining stagnant water of 5-7 cm above the soil surface. Pest control was done by spraying the insecticides Decis 25 EC especially for soybean and Sevin 80 WSP especially for the *Leptocorisa* plant-hoppers during seed filling stage.

Observation variables and data analysis

Growth variables including plant height, number of leaves and tillers were measured every week, while the yield components include the number of productive tillers, panicle length, number of grains per panicle, dry grain yield per pot, and weight of 100 grains were measured after harvest. Rhizosphere soil sampling was done at the age of 56 days after sowing/transplanting at 10 cm beside the planting hole up to the depth of 7.5 cm below the surface using a soil sampler of 1 inch diameter, for observation of AMF colonization and number of AMF spores. AMF colonization observations made by the gridline intersect method (Giovannetti and Mosse, 1980) after the root fragments were cleared with 10% KOH followed by HCl 2% and stained with trypan blue of 0.05% in lacto-glycerol (distilled water + lactic acid and glycerol 1: 1: 1), using the modified technique of clearing and staining used by Wangiyana (2004). However, only the growth data are reported here, since the rest of the data have not ready for reporting. Data were analyzed using CoStat for Windows, with analysis of variance (ANOVA) and Honestly Significant Difference (HSD) test at 5% significance level.

RESULTS AND DISCUSSION

Based on the ANOVA results summarized in Table 1 it appears that only the interaction between the techniques of rice cultivation and varieties show significant interaction, but only on the number of leaves and number of tillers at the age of 8 weeks after planting (WAS), and on the rate of increase in the number of tillers, whereas the effect of each treatment factor (main effect) mostly show a significant effect, especially the factor of varieties or red rice lines, which showed a significant effect on all the observation variables, while the technique of rice cultivation showed non-significant effect only on the growth rate of plant height, and organic fertilization factor was non-significant only on plant height 8 WAP and growth rate of plant height.

Based on the main effects, it can be seen from Table 2 that aerobic rice system without intercropping with soybean resulted in highest growth rates, leaf number and tiller number, which are also higher in aerobic without soybean compared with in the aerobic system intercropped with soybean, except for plant height. This means that intercropping with soybean could reduce leaf and tiller numbers and their growth rates. Application of organic fertilizer also resulted in higher growth rates, leaf number and tiller number, except for plant height.

Tabel 1. Summary of ANOVA results on plant height, leaf number, and tiller number at 8 weeks after planting (WAP), as well as growth rates of plant height, leaf number, and tiller number

Observation Variabels	Main effects			Interaction effects			
	Tech	Var	Org	T*V	T*O	V*O	T*V*O
Plant height 8 WAP	***	**	ns	ns	ns	ns	ns
Growth rate of plant height	ns	**	ns	ns	ns	ns	ns
Leaf number 8 WAP	***	*	***	**	ns	ns	ns
Growth rate of leaf number	***	*	***	ns	ns	ns	ns
Tiller number 8 WAP	***	**	**	**	ns	ns	ns
Growth rate of tiller number	***	**	**	***	ns	ns	ns

Remarks: ns = non-significant; *, **, *** = significant at $p<0.05$; $p<0.01$; $p<0.001$ respectively

Table 2. The main effects of rice cultivation techniques (T), Red rice line/variety, and Organic fertilization on plant height, leaf number and tiller number at 8 WAP, as well as average growth rates of leaves and tillers per week

Treatment factors	Plant height (cm) 8 WAP		Leaf number at 8 WAP		Tiller number at 8 WAP		Average growth rate per week			
							Leaves		Tillers	
Rice Cultivation :										
T1=Conventional	98.1	a	87.3	b	23.0	c	9.76	c	1.99	c [1)]
T2=Aerobic+Soy	74.6	b	95.7	b	28.0	b	16.20	b	4.42	b
T3=Aerobic	77.5	b	120.3	a	38.7	a	21.87	a	6.90	a
HSD 0.05	3.4		8.8		2.5		1.68		0.53	
Red rice lines :										
V1=Amp.G2	82.3	b	109.1	a	32.9	a	17.24	a	5.01	a
V2=Amp.G4	81.8	b	98.2	a	29.0	b	14.94	b	4.00	b
V3=Amp.G9	82.2	b	98.6	a	29.2	b	15.88	ab	4.43	ab
V4=Amp.G10	87.2	a	98.6	a	28.6	b	15.69	ab	4.31	b
BNJ 0.05	4.3		11.2		3.2		2.14		0.68	
Organic fertilization:										
O0=Without organic	83.8	a	93.1	b	28.4	b	14.68	b	4.18	b
O1=With organic	83.0	a	109.1	a	31.4	a	17.21	a	4.69	a
HSD 0.05	2.3		6.0		1.7		1.14		0.36	

Remarks: 1) Figures in each column followed by the same letter are not significantly different between levels of each treatment factor

From Figure 1, it can be seen that plant height of the red rice lines grown on the conventional cultivation techniques are on the average significantly higher compared with those grown on aerobic systems, either without or with soybean growing together in the pots. This may mean that the aerobic system, especially those grown along with soybeans, will reduce rice plant height.

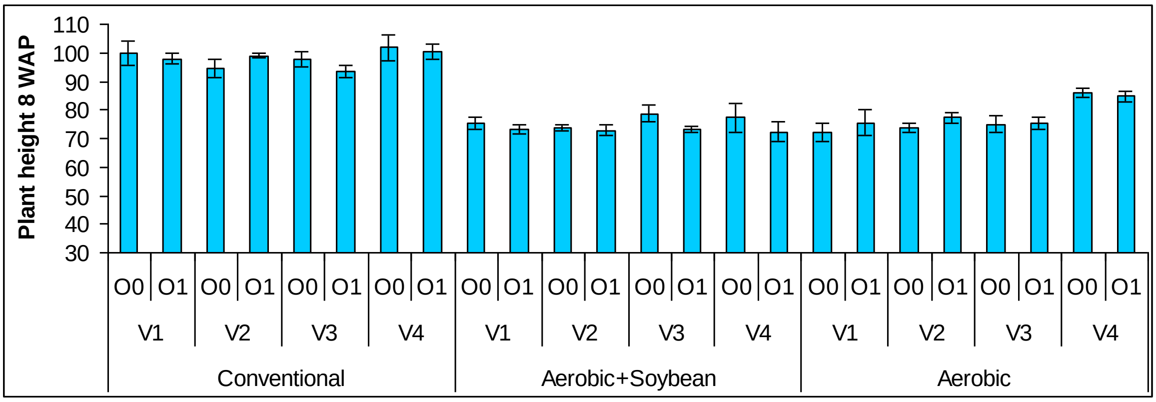

Figure 1.Average (Mean ± SE) plant height of several amphibious red rice lines on combinations of rice growing techniques and organic fertilization (O0 vs O1)

On the contrary, from Figure 2 and Figure 3, it appears that the number of leaves and number of tillers are lowest on the conventional technique, in which rice plants were flooded. Maybe that's why, when rice plants are not expected to produce seedlings, because it was already too late, it is suggested to flood rice crop as high as 10 cm, to inhibit the growth of late tillers (Deptan, 1977). This means that the aerobic system can increase the number of tillers, followed by leaf number, since there is no flooding. It could be possible that the biomass in rice plants grown on aerobic systems is more allocated to production of tillers and leaves instead of growing upward, so that plant height of rice on the aerobic system is on average lower than that on the conventional technique.

With regard to tiller number, this aerobic rice system seems to be similar to SRI technique of growing rice, which avoids prolonged flooding. And with the SRI technique, rice productivity can be improved, which in Madagascar could reach an equivalent grain yield of 21 t/ha on a paddock in which the SRI technique of growing rice has been practiced for 5 years, while the conventional techniques on the plots adjacent to it only produced an average yield of 2.6 t/ha (Uphoff, 2002). The high grain yield of rice on an SRI technique is supported by the high number of tillers. In this research, tiller number also significantly higher on the aerobic system compared with on the conventional technique. Unfortunately until this article was written, the data of grain yield still can not be obtained because it was still in the process of measurement. Moreover, with aerobic techniques, the rice plant can be grown in intercropping systems with legumes such as soybeans, although in terms of the number of tillers, it appears that soybean has adverse effects. However, there is a chance that the soybean crop could support to better nutrition of the rice plants, as has been reported to happen on sorghum intercropped with soybean (Ghosh *et al.*, 2006). In addition soybean grown together with rice in the aerobic system in this research can also increase productivity of the system because of the additional grain yield of soybean in addition to rice grain yield, since growth of the soybean plants grown alongside the rice plants did not seem much disturbed.

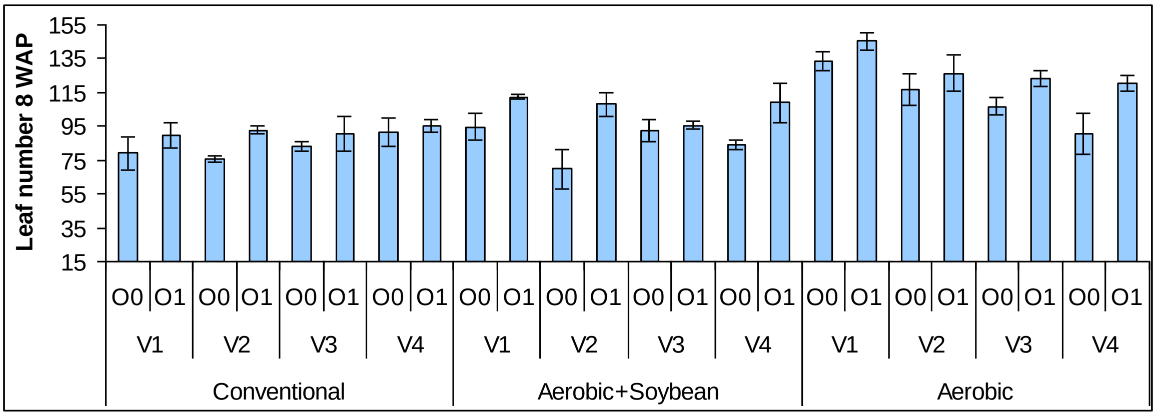

Figure 2.Average (Mean ± SE) leaf number per pot of several amphibious red rice lines on combinations of rice growing techniques and organic fertilization (O0 vs O1)

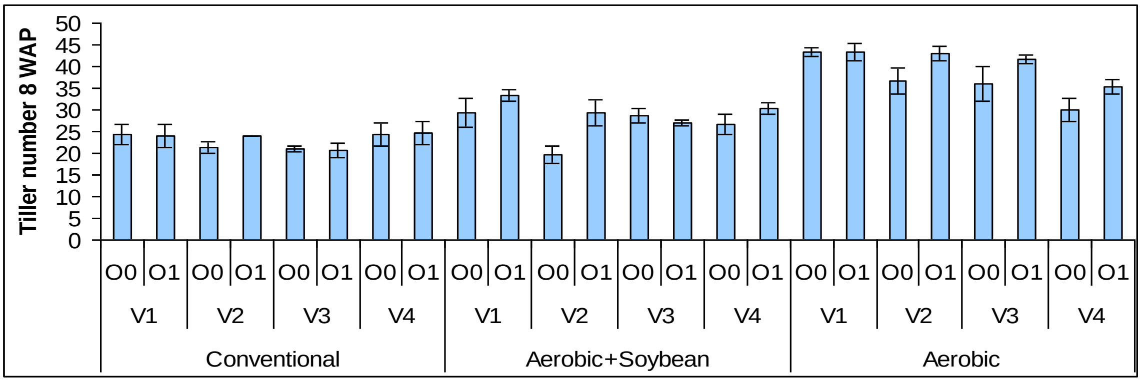

Figure 3.Average (Mean ± SE) tiller number per pot of several amphibious red rice lines on combinations of rice growing techniques and organic fertilization (O0 vs O1)

If seen from Figure 1, Figure 2 and Figure 3, it appears that the effects of the organic fertilizer application using Bokashi compost are mostly non-significant, especially on tiller number in conventional rice cultivation techniques, while in the aerobic systems, the effects are mostly significant. As can be seen from the treatments, the difference between the conventional techniques and aerobic systems is in terms of irrigation, in which the soil in the pots in the conventional technique was always in flooded condition except at the time of inorganic fertilization, while in the aerobic systems, the soil is never flooded because irrigation water was supplied through "sub-irrigation". This means that flooding affects the rice crop response to organic fertilization using Bokashi compost from cattle manure.

CONCLUSION

Based on the results and data analysis it can be concluded that the varieties or types of the red rice lines and cultivation techniques provided a dominant influence on the growth of various amphibious red rice lines, whereas a significant interaction occurred only between varieties and cultivation techniques. Aerobic rice system resulted in rice plants with higher number of leaves and tillers per pot when compared with the conventional technique. In addition, the response of rice crop to compost application was also better in the aerobic systems compared with in the conventional technique.

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