

Effect of Relay-Planting Several Legume Species at Various Ages of Rice on Growth and Yield of Red Rice Grown Together with Legume Crops under Aerobic Irrigation System

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Abstract— This study aimed to examine the effects of relay-planting several species of legume crops at various ages of rice plants on growth and yield of red rice grown together with legume crops in pot culture under aerobic irrigation systems. The pot experiment was carried out in a plastic house from August to December 2018, designed according to the Complete Randomized Design with three replications and two factorial treatment factors, namely legume species (s_1 = peanut var. *Hypoma-3*, s_2 = mungbean var. *Kenari*, s_3 = soybean var. *Dering-1*), and ages of red rice when the legume crops were relay-planted (u_1 = relay-planting at 1 week after seeding rice (WASR), u_2 = 2 WASR, u_3 = 3 WASR, and u_4 = 4 WASR). The results indicated that the ages of rice when the legume crops were relay-planted showed more significant effects on growth and yield components of the red rice compared with the legume species did, but there were no interaction effects between the two treatment factors tested. Among the various ages examined, relay-planting legume crops when the red rice age was 3 weeks resulted in the highest growth and yield components of the red rice examined, in which the mean values of tiller number (26.2 tillers/clump), panicle number (20.4 panicles/clump), filled grain number (1030 grains/clump), and grain yield (26.88 g/clump) were highest compared with relay-planting legume crops at other times. Among the species of legume crops examined, mungbean var. *Kenari* grown together with the red rice resulted in the highest average of red rice grain yield (25.99 g/clump) as well as the highest harvest index (47.01%) compared with the other legume species.

Keywords— red rice, aerobic rice system, legume crops, relay-planting, intercropping

I. INTRODUCTION

Red rice can be used as a high health value food source due to its higher contents of anthocyanins, fibers, and vitamins B and E, compared with white rice [1]. In addition, its economic values are also high so that increasing the productivity of red rice can be used to overcome various food, nutrition and economic problems, especially in Indonesia. Over the past few years, the need for red rice has continued to increase in accordance with the increasing people's awareness on the importance of health and recognition of the health benefit from consuming red rice instead of white rice. However, most of the existing red rice varieties are upland rice varieties, which are generally low in their average productivity [2]. Therefore, it is necessary to increase the productivity of red rice through application more productive rice cultivation technologies, one of which is by growing red

rice under aerobic irrigation techniques, which was called as aerobic rice systems (ARS) [3]. One of the advantages of growing rice under ARS is that it can be intercropped with legume crops [4], and legume crops have the potentials to fix atmospheric nitrogen to increase nitrogen content of the soil, which can increase productivity and sustainability of crop production systems [5]. In relation to intercropping, Inal *et al.* [6] reported that maize-peanut intercropping could induce an increase in concentration of nutrients in their rhizospheres, and increased concentrations of nutrients in the shoots of the maize and peanut plants.

In relation to benefits of intercropping rice plants with legume crops in aerobic irrigation systems, results of previous researches have shown that growing-together rice plants in one pot or intercropping rice plants on raised-beds with legume crops could increase growth and yield of

rice plants, either without or with application of mycorrhiza bio-fertilizers. For example, Dulur *et al.* [7] reported that various promising lines of red rice grown in pot culture under aerobic irrigation systems resulted in significantly higher numbers of leaves, tillers and filled panicles per clump compared with rice plants grown under conventional or flooded system. Grain yield of two genotypes of red rice was also significantly higher under aerobic irrigation than under flooded system in pot culture, either in intercropping with soybean or without soybean [8]. Wangiyana *et al.* [4] also reported that various rice genotypes including upland, amphibious and paddy rice genotypes grown together with soybean in pot culture under aerobic irrigation system produced greener leaves and higher percentages of tillers producing filled panicles compared with those grown in monocrop under aerobic irrigation system.

Those greener leaves of rice plants in rice-soybean system could be due to some transfer of biologically fixed-N from soybean to rice, as those reported by Chu *et al.* [9], who measured significant amount of N transfer from peanut to rice plants grown in intercropping under aerobic system, which resulted in higher N accumulation, chlorophyll content, filled tiller number, dry matter, and 1000-grain weight of rice plants in intercropping with peanut than in monocrop. Under permanent raised-bed growing conditions, Dulur *et al.* [10] also reported higher panicle number and higher filled grain number per clump in red rice intercropped with peanut than those in monocrop rice or conventional rice. Wangiyana *et al.* [11] also reported that additive intercropping various genotypes of red rice with soybean var. Dering-1 on raised-beds significantly increased rice grain yield, especially when inoculated with arbuscular mycorrhizal fungi (AMF), compared with those in monocrop.

In addition to the effects of different varieties or species of legume crops intercropped with rice or cereal crops, the timing of relay-planting the legume crops relative to the ages of the cereal crops grown in cereal-legume intercropping systems also reported to have some effects on growth and yield of both cereal and legume crops in the intercropping systems. Farida *et al.* [12], for example, reported that delaying the relay-planting of peanut between double or triple rows of red rice plants in aerobic irrigation system on raised-beds increased panicle number per clump, compared with relay-planting one week after seeding the red rice. In intercropping maize with two legume cover crops (*Mucuna* and *Canavalia*) planted at 0, 2, 4, and 6 weeks after planting maize (WAPM), Lawson *et al.* [13] reported that planting the legume cover crops 6 WAPM resulted in the highest maize grain yield compared

with planting legume earlier, but grain yields of the legume cover crops were highest in the earliest planting time and lowest in the in the latest planting time. In addition, Armstrong *et al.* [14] also reported that delayed planting of lablab bean, velvet bean and scarlet runner bean in intercropping with maize from 2 to 4 weeks increased maize grain yield, but decreased yield of the bean crops. In these two cases, both in [13] and in [14], it could mean that there was stronger competition by the legume crops for maize yields in the earlier planting time of the legume crops, or vice versa. Therefore, the timing of relay-planting of legume crops in intercropping with cereal crops may be very important in order to increase the crop's yield through intercropping systems.

This research was aimed to examine growth and yield of red rice as affected by different relay-planting dates of several species of legume crops in intercropping or growing together with red rice in pot culture under aerobic irrigation systems in a plastic house.

II. MATERIALS AND METHOD

Design of experiment

The pot experiment in this study was conducted in a plastic house located in the experimental farm of the Faculty of Agriculture, University of Mataram, which is located in Narmada District of West Lombok, Indonesia, from September 2018 to January 2019. The experiment was designed according to the Completely Randomized Design, with three replications and two treatment factors, namely: species of legume crops grown together (intercropped) with red rice in a pot culture (s1= peanut var. Hypoma-3; s2= mungbean var. Kenari; s3= soybean var. Dering-1), and relay-planting dates (u1= relay-planting legume crops at 1 week after seeding rice (WASR); u2= 2 WASR; u3= 3 WASR; u4= 4 WASR). To be able to calculate the land equivalent ratio (LER) of grain yield per clump, pot culture of monocrop red rice and each legume crop was also established each with three replications.

Implementation of the experiment

The plastic pots used in this pot experiment were from a previous pot experiment of intercropping various red rice genotypes with soybean [4]. Each pot has 4 circumference side-holes of 9 mm diameter at 1 cm above the pot base for use as sub-irrigation holes. For this experiment, each pot was filled with 7 kg air-dried soil that has been sieved with 2 mm opening sieve, and watered up to the field capacity. The red rice genotype used in this study was the promising amphibious red rice line "F2BC4A86-3" (or "AM-G4") selected from results of a previous research [2]. For planting the red rice, seeding the pre-germinated AM-G4

seeds was done in a seedling tray filled with a mixture of soil and rice husk ash (1:1), which was thinned after one week to allow only two seedlings to grow per hole of the seedling tray. The same procedure was also applied to seeding of the pre-germinated legume seeds, but they were seed-coated with *Rhizobium* inoculant before seeding, and the timing of seeding was in accordance with the treatment of relay-planting dates.

Transplanting those seedlings (rice and legume crops) to the prepared pots was done at 10 days after seeding of each species. In an intercropping pot, red rice seedling and legume seedling were transplanted at 10 cm apart in the center of the soil surface in the pot. For fertilization of the crops, fertilizer type and doses, and timing of fertilization were the same as in the previous research [4]. Irrigation was also done through sub-irrigation using those side-holes of the pots by placing all pots in wooden tank of 10 cm height covered with plastic sheet and filled with water with water surface maintained around 1-2 cm above the side holes, as described in previous research [4]. Other crop maintenance activities were also as described in previous research [4].

Observation variables and data analysis

Observation variables included maximum plant height, number of leaves per clump, number of tillers per clump, average growth rates (AGR) of plant height, leaf number, tiller number, panicle number per clump, filled grain number per clump, percentage of unfilled grain number (calculated from percent of unfilled grain number to total spikelet number per clump), dry straw weight per clump, grain yield (filled grain weight) per clump, weight of 100 grains, and harvest index. Data were analyzed with analysis of variance (ANOVA) and Tukey's HSD tests at 5% level of significance, using the statistical software CoStat for Windows Ver. 6.303.

III. RESULTS AND DISCUSSION

Based on the results of data analysis, the ANOVA results show that there was no significant interaction between the relay-planting dates and species of legumes grown together with rice in pot culture on growth and yield components of the red rice. Compared with the species of legumes grown together with the red rice, the relay-planting dates, i.e. rice ages at which legume crops were inserted, showed more dominant effects, which had a significant effect on the maximum plant height, number of leaves per clump, number of tillers per clump, AGR of leaf number of per week, AGR of tiller number per week, panicle number per clump, filled grain number per clump, percentage of unfilled grain number, weight of filled grains per clump (or grain yield per clump), and harvest index, while the legume species had significant effects only on the number of filled grains per clump, grain yield per clump and harvest index (Table 1).

Based on the average of growth variables, it can be seen in general that there was a tendency for the highest growth of the red rice to occur in the red rice plants grown together with legume crops that were relay-planted at three weeks after seeding rice (3 WASR) and lowest in rice plants relay-planted with legume crops at 1 WASR (Table 2). This indicated that earlier relay-planting those legume crops for intercropping or growing together with the red rice crop in pot culture will result in higher degree of competition for rice growth by the legume crops, and lower degree of competition in later relay-planting time of legume those crops.

Table 1. Summary of ANOVA results of the effects of relay-planting dates and species of legume crops grown together with red rice in pot culture on growth and yield components of the red rice

Observation variables	Relay-planting dates	Legume species	Interaction
Maximum plant height	s	ns	ns
Leaf number per clump	s	ns	ns
Tiller number per clump	s	ns	ns
Average growth rate (AGR) of plant height	ns	ns	ns
AGR of leaf number per clump	s	ns	ns
AGR of tiller number per clump	s	ns	ns
Panicle number per clump	s	ns	ns
Filled grain number per clump	s	s	ns
Percentage of unfilled grain number	s	ns	ns

Dry straw weight per clump	s	ns	ns
Grain yield (filled grain weight) per clump	s	s	ns
Weight of 100 filled grains	ns	ns	ns
Harvest index (%)	ns	s	ns

Remarks: s = significant, ns = non-significant

Table 2. Average plant height, leaf number per clump, tiller number per clump, and average growth rates (AGR) of plant height, leaf number per clump, and tiller number per clump for each level of treatment factors

Treatments	Maximum plant height (cm)	Leaf number per clump at anthesis	Tiller number per clump at anthesis	Average growth rate (AGR)		
				Plant height (cm/week)	Leaf number per clump (leaves/week)	Tiller number per clump (tillers/week)
u1: 1 week	102.11 b	77.44 b	15.00 b	19.74 a	19.07 b	4.04 b ¹⁾
u2: 2 week	108.89 ab	114.44 a	24.00 a	21.48 a	31.72 a	6.59 a
u3: 3 week	111.89 a	121.11 a	26.22 a	21.98 a	33.30 a	6.98 a
u4: 4 week	109.00 ab	109.00 a	24.89 a	20.53 a	29.60 a	6.61 a
HSD 0.05	7.18	21.91	5.13	2.40	6.70	1.54
s1: Groundnut	108.75 a	106.83 a	22.67 a	21.38 a	28.56 a	6.09 a
s2: Mungbean	108.33 a	108.67 a	22.92 a	20.75 a	29.54 a	6.28 a
s3: Soybean	106.83 a	110.00 a	22.00 a	20.68 a	27.17 a	5.80 a
HSD 0.05	5.63	17.18	4.02	1.88	5.25	1.21

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

In relation to competition between legume and non-legume crops in an intercropping system, especially in response to different dates of relay-planting the legume crops, previous researches also reported similar results. Armstrong *et al.* [14] showed that delaying the date of relay-planting lablab bean, velvet bean, and scarlet runner bean between maize rows relative to the maize planting date significantly reduced the bean fodder yield but significantly increased maize fodder yield. Lawson *et al.* [15] also reported that delaying the date of relay-planting soybean, cowpea and groundnut from 0 to 2 and 4 weeks after planting maize reduced leaf area index and shoot biomass of the legume crops.

In relation to yield components of the red rice in this research, the average number of filled panicle per clump, filled grain number per clump, and grain yield per clump also tended to be highest in the pots where the legume crops were relay-planted at 3 weeks after seeding the red

rice (3 WASR), and lowest in the pots where the legume crops were relay-planted at 1 week after seeding the red rice (Table 3). These data show significant increases with the increasing delay of the dates of relay-planting the legume crops in intercropping (growing together) with the red rice plants in pot culture. These could mean that earlier dates of relay-planting those legume crops may have imposed higher degree of competition with the red rice plants. In relation to different timing of relay-planting legume crops between cereal and legume crops, many have reported similar yield trends in relation to delaying the dates of relay-planting legume crops in intercropping systems, as those reported by Armstrong *et al.* [14]. Lawson *et al.* [13] also reported that maize grain yields increased with delaying the dates of relay-planting Mucuna and Canavalia cover crops between rows of maize in intercropping systems, but the delay decreased grain yield of the legume cover crops.

Table 3. Average panicle number per clump, filled grain number per clump, percentage of unfilled grain number, dry straw weight per clump, grain yield per clump, weight of 100 filled grains, and harvest index for each level of treatment factors

Treatments	Filled panicle number per clump	Filled grain number per clump	Percentage of unfilled grain number (%)	Dry straw weight (g/clump)	Grain yield (g/clump)	Weight of 100 filled grains (g)	Harvest index (%)
u1: 1 week	13.89 b	722.44 b	18.75 b	22.85 b	18.78 b	2.59 a	44.04 a ¹⁾
u2: 2 week	18.77 a	870.89 ab	29.37 a	34.19 a	22.85 ab	2.63 a	41.06 a
u3: 3 week	20.44 a	1030.00 a	27.00 ab	31.93 ab	26.88 a	2.59 a	45.57 a
u4: 4 week	17.11 ab	989.89 a	20.77 ab	30.43 ab	26.17 a	2.64 a	46.56 a
HSD 0.05	2.97	187.77	7.03	7.15	4.84	0.11	6.28 a
s1: Groundnut	16.33 a	921.58 ab	20.36 a	28.61 a	24.51 ab	2.65 a	46.42 a
s2: Mungbean	18.42 a	998.83 a	25.35 a	29.80 a	25.99 a	2.61 a	47.01 a
s3: Soybean	17.92 a	789.50 b	26.21 a	31.13 a	20.51 b	2.58 a	39.50 b
HSD 0.05	2.57	160.01	6.09	6.19	4.19	0.09	5.44

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

In relation to yield of cereal crops in intercropping with legume crops, some reported lower yield of intercropped than monocropped cereal crops, such as those reported by Lawson *et al.* [13] and Lawson *et al.* [15] regarding to yield of maize in intercropping with some legume crops. However, many reported yield advantages for cereal crops when intercropped with legume crops, or no yield differences, compared with monocropped cereal crops. From an intercropping system of wheat-soybean, Li *et al.* [16] reported higher grain yield of wheat per ha in intercropping with soybean compared with in monocropped wheat, and yield differences were higher in higher doses of P fertilizer. However, from the results reported by Jeranyama *et al.* [17], maize grain yield was not reduced by intercropping with cowpea or *Crotalaria juncea* when maize was fertilized with 0-60 kg/ha N, but when it was fertilized with 120 kg/ha N, its grain yield was reduced, compared with monocropped maize. This could mean that under low N fertilization, maize plants would get some N transfer from rhizosphere of legume crops in an intercropping with maize.

In relation to N contribution from legume to cereal crops in intercropping systems, Fujita *et al.* [18] reported that N transfer from soybean to sorghum, which resulted in higher dry matter production by sorghum in intercropping than in monocropping, was highest in the closest planting distance between both crops. Chu *et al.* [9] also reported N transfer from peanut to rice plants grown in intercropping under aerobic system, resulted in higher filled panicle number, spikelet weight and weight of 1000 seeds of the rice plants in intercropping than in monocropping system. Inal *et al.* [6] found that intercropping maize with peanut resulted in higher concentration of nutrients in rhizosphere and in the shoots of both crops. Previous researches using

this red rice also reported that grain yield of red rice grown in aerobic irrigation system was higher in intercropping with legume crops than in monocropped or conventional red rice, for example those reported by Dulur *et al.* [8] and Wangiyana *et al.* [11] in intercropping red rice with soybean, and Dulur *et al.* [10] in intercropping red rice with peanut.

Based on the grain yield per clump in this research, however, the average grain yield was very low, i.e. the highest average of 25.99 g/clump in intercropping with mungbean, and the lowest average of 20.15 g/clump in intercropping with soybean (Table 3). These are much lower than those reported by Dulur *et al.* [8] under the same experimental site, i.e. under pot culture using soil from the same land in the same plastic house, with the highest average of 34.73 g/clump in intercropping with soybean. From field experiments conducted in other locations, by growing red rice on permanent raised-beds under aerobic irrigation systems, some researchers reported higher grain yields of red rice, i.e. 54.49 g/clump in intercropping with soybean [11], and 2632 filled grains per clump in intercropping with peanut [10]. The low grain yield of the red rice obtained in this research was probably due to prevalent attacks by stink bugs (*Leptocoriza acuta*) during the seed-filling stage, which resulted in a very high average of percentage of unfilled grain number, i.e. up to 29.37% (Table 3).

Among the legume crops examined for intercropping with red rice in pot culture, different species of those legume crops resulted in differences only in some yield components of the red rice tested, including filled grain number per clump, grain yield per clump, and harvest index (Table 3). In terms of their effects on grain yield of the red rice, mungbean of "Kenari" variety was found to

be the best among those legume species intercropped with the red rice in pot culture, which resulted in the highest average of red rice grain yield (25.99 g/pot), while intercropping with soybean var. "Dering-1" resulted in the lowest average of red rice grain yield (20.51 g/pot). Wangiyana *et al.* [19] reported that among five varieties of mungbean tested for intercropping with red rice, the "Kenari" variety resulted in the highest average of red rice grain yield (27.37 g/pot).

However, between both treatment factors, the dates of relay-planting those legume crops had more dominant effects on growth and yield components of red rice in intercropping with legume crops under aerobic irrigation system because it seems to be related to the balances between competition and fixed-N contribution by legume crops to the red rice in intercropping with legume crops. The levels of N contribution by legume crops to non-legume crops in intercropping system also depend on levels of fertilizer doses applied to the crops, as reported by other researchers [16], [17]. Therefore, before a recommendation can be made, more extensive researches need to be done in different conditions of crop production systems to find out the best combination of rice and legume crops to be grown in intercropping systems.

IV. CONCLUSION

It can be concluded the dates of relay-planting legume crops for intercropping with red rice had significant effect on growth and yield of red rice, and relay-planting the legume crops 3 weeks after seeding the red rice was found to be the best timing.

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