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Relay-planting of Peanuts between Double or Triple Rows at different dates Increases Growth, Nitrogen content, and Yield of Red Rice under Aerobic Irrigation Systems

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Abstract— Previous studies reported that intercropping rice with legume crops such as soybean, peanut and mungbean increased nutrient uptake and yield of rice plants. This study aimed to examine the effects of relay-planting peanuts between double or triple rows of rice at different dates on growth, nitrogen content, and yield of red rice in aerobic irrigation systems on raised beds. The experiment was conducted in Narmada (West Lombok, Indonesia), arranged according to Split Plot design with two treatment factors, i.e. rice row patterns as the main plots (P1= double, P2= triple rows) and relay-planting dates of peanut as the subplots (T0= without peanut; T1= relay-planting peanut 1 week, T2= 2 weeks, T3= 3 weeks after seeding pre-germinated red rice seeds). Results indicated that between the treatment factors, relay-planting peanut at different dates resulted in significant effects on more variables compared with the patterns of rice rows. However, there were significant interaction effects between the treatment factors on tiller and panicle numbers per clump, and higher panicle number supported by higher leaf N content and higher harvest index resulted in significantly higher grain yield of the red rice intercropped with peanuts, especially when peanut was relay-planted at three or two weeks after seeding the pre-germinated rice seeds on raised-beds in aerobic irrigation systems. Although there was no significant effect of row patterns, the highest grain yield average (75.96 g/clump) was on T3 treatment under triple-row and the lowest average (33.29 g/clump) was on T0 treatment under double-row pattern.

Keywords— Peanuts, red rice, intercropping, aerobic irrigation systems, row patterns.

I. INTRODUCTION

Rice (*Oryza sativa* L.) is grown in at least 114 countries of the world, and together with maize and wheat, these crops produce staple food, but rice becomes the most important among these three food crops with respect to human nutrition and caloric intake. In addition, rice is an extremely versatile crop, which can grow in various different environmental conditions, i.e. from dry to flooded condition, and from low to high altitudes [1]. However, rice is not just staple food. Rice has a lot of advantages for human health because rice contains various biomolecules capable of health-promotion and therapeutic activity, especially the colored grain rice [2].

Rice has been traditionally grown under flooded conditions (conventional technique), and this has been practiced for a long time due to some advantages, such as

weed suppression and ease of plowing. However, this conventional technique of growing rice is highly inefficient in using irrigation water [1]. In addition, growing rice under flooded condition makes rice as the most inefficient use of nutrients, especially N, because flooded conditions increase N losses through leaching, denitrification, and volatilization, while grain yield is low under conventional techniques with a world average of 5 ton/ha [3]. The majority of the N loss from Urea applied was through ammonia volatilization, which reached up to 88% of the total N loss [4]. In addition, conventional technique of rice production is also a source of P leaching, which causes pollution of the downstream areas [5].

There have been some non-conventional techniques developed elsewhere. One of which is the system of rice intensification (SRI), which applied intermittent irrigation

5 water during vegetative growth stages and thin flooding during the reproductive stages of rice growth. From the results of practicing the SRI technique in Madagascar, where this technique was initially developed, it was reported that the maximum rice yield was up to 21 ton/ha with a maximum average of 13.9 ton/ha, while under conventional technique on comparable land, rice yield ranged from only 1.5 to 3.6 ton/ha [6].

Another non-conventional technique of growing rice recently developed is aerobic rice system (ARS), in which rice is grown on non-flooded, non-saturated and non-puddled soil conditions [7], [8]. One of the advantages of growing rice under aerobic irrigation system is aerobic conditions of the soil. Since the soil is not flooded, then it is possible to grow rice in intercropping with legume crops for better nitrogen nutrition. Chu et al. [9] reported that under rice-peanut intercropping, there was significant N transfer from peanut to rice plants. Wangiyana et al. [10] also reported that inoculation of arbuscular mycorrhizal fungi (AMF) on rice plants grown together in pot culture with peanut significantly increased grain yield of red rice under aerobic irrigation systems.

This study aimed to examine the effects of relay planting peanut at different dates between double or triple rows of red rice on growth, leaf nitrogen content, and yield of a promising line of red rice grown on raised-beds under aerobic irrigation systems.

II. MATERIALS AND METHODS

The field experiment in this study was conducted on paddy field in the Experimental Farm of the Faculty of Agriculture, University of Mataram, located in Narmada (Lombok, Indonesia) from June to October 2016. The experiment was arranged according to Split Plot design, testing two treatment factors, namely: the patterns of rice rows (P) as the main plots (P1= double row, P2= triple row), and intercropping (T) with peanut plants relay-planted between the double or triple rows of rice plants at various ages of the rice plants on the raised-beds (T0 = without intercropping, T1= relay planting peanut 1, T2= 2, T3=3 weeks after planting (WAP) pre-germinated rice seeds) as the subplots. Each treatment combination was made on three blocks. The details of the treatments and the implementation of the experiment were as described in Farida et al. [11].

The observation variables include plant height, leaf number and tiller number at 12 WAP, panicle number, total N concentration in the rice leaves, dry straw weight and grain yield per clump, weight of 100 grains, and

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harvest index. For leaf N content, oven-dried samples of rice leaves taken during anthesis were sent to the Analytical Laboratory of Mataram University for quantification of total N content. Harvest index was calculated from percentage of grain yield of the total harvested above-ground rice plant biomass including the grains, after being dried. Data were analyzed with analysis of variance (ANOVA) and Tukey's HSD at 5% level of significance, using the statistical software CoStat for Windows ver. 6.303.

III. RESULTS AND DISCUSSION

The summary of ANOVA results in Table 1 shows that between the two treatment factors tested, relay-planting or additive intercropping with peanuts shows significant effects on more variables, especially on grain yield per clump, compared with row patterns of the rice plants. However, there were significant interaction effects between relay-planting of peanut at different dates and row patterns of rice plants on tiller number per clump (Figure 1), and panicle number per clump of the red rice (Figure 2).

In addition to significant interaction effects, relay-planting of peanut and row patterns of rice plants also show significant main effects both on tiller number and panicle number, as it can be seen from Table 1, that relay-planting peanuts at two or three weeks after seeding the pre-germinated red rice seeds significantly increased tiller and panicle number per clump. However, there were interaction effects between the two treatment factors, as can be seen from Figure 1 for tiller number and Figure 2 for panicle number.

It can be seen from Figure 1 that the highest tiller number per clump of red rice plants grown under triple-row pattern was on the red rice plants intercropped with peanut relay-planted at two weeks after seeding the pre-germinated rice seeds, while under double-row pattern, the highest tiller number was on the red rice plants intercropped with peanut relay-planted at three weeks after seeding the pre-germinated rice seeds. The trend was also very similar on panicle number per clump, as can be seen from Figure 2.

This means that the peak N contribution of relay-planting peanut plants on highest tiller number per clump will be achieved when pre-germinated seeds of peanuts were relay-planted between two and three weeks after seeding the pre-germinated red rice seeds. According to the results reported by Chu et al. [9], the highest contribution of N transferred from peanut to rice was up to

11.9% of the rice N, and they relay-planted peanut seeds at four weeks after seeding rice.

Table.1: Summary of ANOVA results of the effects of intercropping with peanut and row patterns of red rice on growth, nitrogen content, and yield components of red rice on raised-beds under aerobic irrigation systems

Treatments:	Plant height 12 WAP (cm)	Leaf number 12 WAP	Tiller number 12 WAP	Panicle number per clump	Leaf total N concentra- tion (%)	Dry straw weight (g/clump)	Weight of 100 grains (g)	Grain yield (g/clump)	Harvest index (%)
Intercropping:									
T0: monocrop	112.50 a	55.17 b	17.50 c	16.17 c	2.67 b	60.04 b	2.45 a	33.98 c	35.99 b ¹⁾
T1: 1 week	107.50 a	60.43 ab	24.17 b	23.33 b	2.72 b	80.00 a	2.44 a	57.89 b	41.94 a
T2: 2 weeks	113.83 a	61.83 a	27.17 a	25.83 a	2.82 ab	90.11 a	2.57 a	69.14 a	43.56 a
T3: 3 weeks	114.00 a	65.67 a	28.33 a	26.67 a	2.93 a	90.34 a	2.41 a	70.80 a	43.90 a
HSD 5%	ns	6.59	2.56	2.08	0.15	15.28	ns	7.92	5.40
Row patterns:									
P1:double-row	110.08 a	56.42 a	22.92 b	21.67 b	2.78 a	78.74 a	2.48 a	55.89 a	40.84 a
P2:triple-row	113.83 a	65.13 a	25.67 a	24.33 a	2.89 a	81.51 a	2.46 a	60.02 a	41.86 a
HSD 5%	ns	ns	2.48	2.59	ns	ns	ns	ns	ns
Interactions	ns	ns	s	s	ns	ns	ns	ns	ns

¹⁾ Mean in each column with same letters indicates non-significant differences between levels of a treatment factor
 Note on ANOVA results: ns = non-significant; s = significant (p -value < 0.05)

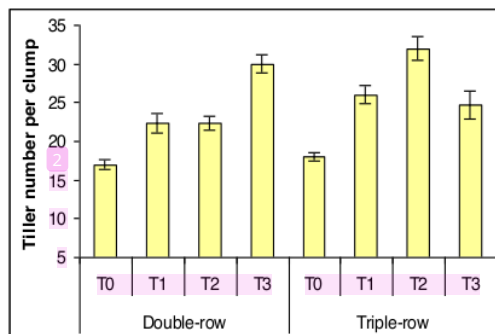


Fig.1: Interaction effects of the treatments on tiller number per clump

In relation to leaf total N content of the red rice plants, although there was no interaction effect of the treatment factor, it can be seen from Table 1 that the highest concentration of N in the rice leaves was on the red rice plants intercropped with peanuts relay-planted at three weeks after seeding the pre-germinated red rice seeds, and leaf N concentration was not significantly different

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between the patterns of rice rows. These averages of leaf total-N contents were in good correlation with average grain yield per clump with an $R^2 = 64.11\%$ (p -value = 0.055). In addition, panicle number per clump also highly correlated with average grain yield per clump, with an $R^2 = 98.11\%$ (p -value < 0.001).

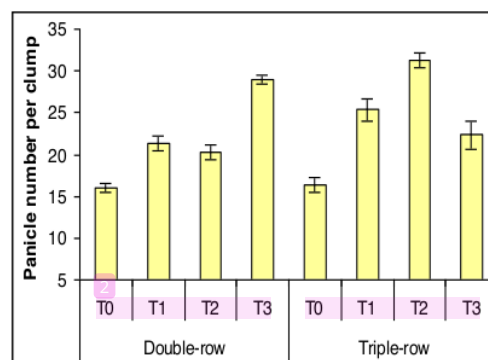


Fig.2: Interaction effects of the treatments on panicle number per clump

With higher averages of panicle number of the red rice plants in the T3 and T2 treatments compared with those in the T1 and T0 treatments supported with higher content of total N in the leaves, these will ensure the seed-filling process to run well to produce higher averages of grain yield under T3 and T2 treatments compared with under T1 and T0 treatments (Table 1). According to results reported by Sinclair and de Wit [12], seed plants require sufficient concentration of leaf N during seed-filling stage for sufficiently high photosynthetic rates during the seed-filling stages, otherwise the plants will remobilize their leaf N to the growing seeds resulting in acceleration of leaf senescence, especially in legume crops, such as soybean, due to the high N requirement of legume crops for the seed protein content.

Although there was no significant interaction effect between the treatment factors on grain yield of the red rice in this study, it can be seen from Figure 3 that the highest average of grain yield was different between different patterns of rice rows. Under double-row pattern, the highest average of grain yield was in the red rice plants intercropped with peanut relay-planted at two weeks after seeding rice (T2), and under relay-planting peanut at three weeks after seeding rice (T3), average grain yield was lower in T3 than in T2. In the double-row pattern, the row distance between the double-rows was 30 cm while in the triple-row pattern it was 35 cm. It was highly possible that peanut plants whose seeds were relay-planted three weeks after seeding rice was more quickly shaded by the higher rice plants in the double-row pattern at three weeks after rice seeding compared with those on the double-row pattern at two weeks after seeding rice. Therefore, peanut growth in the double-row pattern of rice plants was possibly better when relay-planted at two weeks after seeding rice compared with relay-planting at three weeks after seeding rice, so that N contribution to rice could be higher from the peanut plants relay-planted two weeks compared with three weeks after seeding rice. In contrast, in triple-row pattern, the space between triple-rows, where peanut plants were relay-planted was wider than in double-row pattern, so that relay planting peanut three weeks after seeding rice could contribute more N due to closer timing of maximum N-fixation rates and highest N requirement of the red rice plants. Chu et al. [9] conducted relay-planting of peanut seeds at four weeks after seeding rice seeds in an intercropping system.

In relation to harvest index, it can be seen from Table 1 that intercropping the red rice plants with peanut resulted in significantly higher harvest index compared with monocropped red rice plants. This could mean that higher harvest indices in the red rice plants under T3 and T2

compared with under T1 or T0 was most probably due to higher leaf N content of the red rice plants under T3 and T2 compared with under T1 and T0. As has been reported by Sinclair and de Wit [12], sufficiently higher leaf N content is required to ensure sufficiently high rate of photosynthesis during the grain-filling stages. If leaf N content is very low then the photosynthetic rates during the seed-filling stage will be insufficient for the growing seeds even though the average panicle number per clump is high, and this will result in lower harvest index compared in the rice plants containing sufficient leaf N.

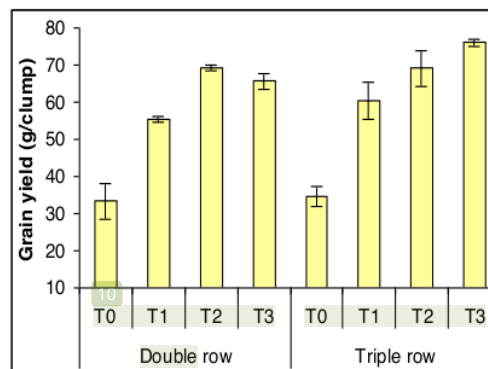


Fig.3: Average (Mean \pm SE) grain yield (g/clump) of red rice as affected by relay-planting peanut at different dates between double and triple rows of rice

According to the results reported by Inal et al. [13], intercropping maize with peanut increased the availability of the nutrients in the rhizosphere of the intercropped plants compared with its monocrop, and this makes nutrient contents in the plants grown under intercropping system compared with under monocropping system. Therefore, it is clear why the red rice plants intercropped with peanut relay-planted at one, two or three weeks after seeding pre-germinated seeds of the red rice, which was probably due to the higher N contents of the red rice plants intercropped with peanut, especially when peanut was relay planted three weeks after seeding rice. Arifuddin et al. [14] also reported that relay-planting legume crops, including peanut of Hypoma-3 variety, mungbean of Kenari variety, and soybean of Dering-1 variety, at three weeks after seeding red rice seeds was found to result in the highest tiller number, panicle number, filled grain number, and grain yield per clump of red rice plants grown together with those legume crops in pot culture under aerobic irrigation systems.

IV. CONCLUSION

It can be concluded that intercropping red rice plants with peanuts significantly increased grain yield of the red rice plants due to higher panicle number per clump supported by higher leaf N contents and higher harvest index of the rice plants intercropped with peanut, especially when peanut was relay-planted at three or two weeks after seeding the pre-germinated seeds of the red rice.

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