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Residual Effect of Organic Waste Mulching and Intercropping Aerobic Rice with Peanut on Yield Performance of Mungbean Direct-seeded Following Rice on Raised-beds in Lombok, Indonesia

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ABSTRACT: In Indonesia, in the paddy fields, mungbean is generally planted in the dry season as a rotation crop for rice when irrigation water is insufficient for growing rice, so the productivity of mungbean is generally very low. This research aims to determine the impact of cultivation techniques of aerobic-irrigated red rice grown on permanent raised-beds applied with various organic wastes on growth and yield of mungbean direct-seeded following harvest of red rice. The experiment carried out in June-August 2020, was arranged according to Split Plot design, with two treatment factors: techniques of cultivating aerobic-irrigated red rice, as main plots (T1: monocrop; T2: intercropping with peanuts), and application of various organic wastes to the red rice, as subplots (L0: no waste, L1: rice husks, L2: rice husk ash , L3: rice husk ash + cattle manure). The results indicated that techniques of red rice cultivation and application of various wastes to the red rice showed significant interaction effect on pod number and dry filled-pod weight of mungbean direct-seeded following the red rice, in which dry filled-pod weight was highest (14.44 g/clump) in mungbean direct seeded following aerobic-irrigated red rice intercropped with peanuts receiving rice husk ash (T2L2), and lowest (6.74 g/clump) in mungbean direct-seeded following monocropped red rice without organic wastes (T1L0). Both intercropping with peanuts and application of organic wastes to the red rice preceding mungbean, in general, resulted in higher grain yields of mungbean direct-seeded without tillage following harvest of the aerobic-irrigated red rice grown on raised-beds.

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KEYWORDS: Aerobic irrigation; intercropping; mungbean; raised-beds; red rice; peanut

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1. INTRODUCTION

Mungbean (*Vigna radiata* (L.) Wilczek) is a legume crop that has a high economic value and is a source of income for farmers. Indonesia is one of the fourth largest mungbean producing countries after India, Thailand and China with a harvested area of around 300,000 ha/year (Puslitbangtan, 2012). Agronomically, mungbean has several advantages, namely that it is easy to cultivate on less fertile land, it is tolerant to drought, and it is a short-growth duration crop that can be harvested at 56-60 days after seeding. From an economic perspective, the selling price of mungbean is relatively high and stable (Puslitbangtan, 2012). Nutritionally, mungbean is a source of protein (14-33%), iron (5.9-7.9 mg/100 g), and fiber (Dahiya et al., 2015). Mungbean also has the ability to fix N_2 in the air in symbiosis with *Rhizobium* bacteria so that they can improve fertility of the soil (Keatinge et al., 2011).

In Indonesia, mungbean is generally planted during the dry season following the second rice crop or the dry-season rice crop, when the availability of irrigation is insufficient for growing rice, so that mungbean productivity is generally very low due to lack of water. Ruskandar et al. (2015) reported that in the Jatisari-Karawang region, the productivity of post-rice dry season mungbean is around an average of 0.803 tons/ha. However, because mungbean is grown without tillage, fertilization is only with N fertilizer dissolved in water and then poured on the soil around root system, so production costs (planting, materials and maintenance) are also very low, namely IDR. 1,578,000/ha, and with the price of mungbean grains is normally around IDR. 13,000/kg, the farmer gets a fairly high profit, namely IDR. 8,861,000/ha with a B/C ratio of 5.61, which is a relatively very high B/C ratio.

In a rice-legume cropping sequence, the cultivation techniques of rice crop grown preceding mungbean have been reported to have a great influence on the productivity of mungbean direct-seeded without tillage following rice, as reported by Rabani et al. (2021) that mungbean plants direct-seeded following conventional red rice (flooded system) was significantly lower than those direct-seeded following aerobic-irrigated red rice intercropped with peanuts grown together on raised-beds. Soybean plants that are direct-seeded without tillage can achieve higher grain yields if they were direct-seeded following rice crop that was fertilized with organic fertilizer compared to those that were direct-seeded following rice crop without organic fertilization (Dulur et al., 2020a).

One type of organic materials that is very easy to obtain is agricultural waste. The wastes resulted from rice harvest are usually very abundant at harvest time, including in the forms of straw and husks. Rice husks are waste from the milling process which reaches 20-22% of the weight of milled grains (Rohaeti et al. 2015). Sutanto (2002) also stated that rice husks significantly affect the chemical, physical and biological properties of soil. The application of rice husks, rice husk ash and bokashi of cow manure to mungbean plants direct-seeded following red rice was also reported to significantly increase mungbean yields compared to without application of organic materials (Dulur et al., 2020b). Mungbean plants without application of organic fertilizer that are direct-seeded following monocropped red rice under an aerobic irrigation system, showed significantly lower productivity compared to those direct-seeded following aerobic irrigated red rice intercropped with peanuts (Dulur et al., 2020b).

The aim of this research was to determine the impact of intercropping aerobic irrigated red rice with peanuts and the application of various organic wastes to red rice plants on growth and yield of mungbean direct-seeded following the rice crop without tillage.

2. MATERIALS AND METHODS

In this research, an experimental method was used by carrying out the field experiments in Beleke village, Gerung sub-district, West Lombok district, West Nusa Tenggara Province, Indonesia, from June to August 2020. The experiment was organized according to Split Plot Design with three blocks and two treatment factors, namely: (1) Cultivation techniques of the aerobic-irrigated red rice preceding mungbean as the main plot factor (T1: monocrop rice and T2: aerobic-irrigated red rice intercropped with peanuts), and (2) Application of various organic wastes to the aerobic-irrigated red rice as a sub plot (L0: Without organic waste, L1: application of rice husks, L2: rice husk ash, and L3: mixture of rice husk ash and cattle fertilizer). Thus, 8 treatment combinations were obtained, each of which was replicated in three blocks, resulting in 24 experimental units.

Before direct-seeding the mungbean seeds of Vima-4 variety, the remaining of the red rice plants grown on the permanent raised-beds under an aerobic irrigation system and the accompanying weeds were cleaned up by cutting the weeds and the red rice plants close to the soil surface. Thence, mungbean seeds were dibbled without tillage in the ex-stubbles of the preceding red rice plants. So, mungbean planting was carried out like planting soybean seeds as described in Dulur et al. (2020a) but soybean seeds were replaced with mungbean, by burying 3-4 mungbean seeds per planting hole. After thinning the mungbean young plants at 12 days after seeding (DAS) by allowing 2 plants to grow per hole, Phonska (NPK 15-15-15) fertilizer was applied (200 kg/ha dose) by dibbling the fertilizer 1 g/clump. Further care for mungbean plants includes irrigation, weeding and pest control by spraying Prevathon 50 SC insecticide (2 ml per liter of water).

Pod harvest for mungbean was done by harvesting only the mature (brown) pods, and the final harvest was done at 63 DAS by picking up all pods that are brown to black in color. Observation variables included plant height and number of trifoliate leaves at 56 DAS, number of productive branches, number of filled and unfilled pods, weight of dry filled-pods, weight of 100 dry grains, number of grains and grain yield per clump. Data were analyzed with analysis of variance (ANOVA) and Tukey's HSD test at 5% significance level using CoStat for Windows version 6.303

3. RESULTS AND DISCUSSION

The summary of the ANOVA results in Table 1 shows that the different techniques for cultivating red rice on permanent raised-beds under aerobic irrigation systems had a significant effect on several yield components of the mungbean plants direct-seeded following harvest of those red rice plants without tillage, which include such variables as dry pod weight, number of grains, and grain yield per clump of mungbean. In addition, the application of various organic wastes to the aerobic-irrigated red rice also had a significant effect on the yield components of mungbean direct-seeded following the red rice, which include such variables as number of filled pods, number of unfilled pods, weight of dry filled-pods, number of grains, and grain yield per clump. The interaction between cultivation techniques of the red rice and the type of organic wastes applied to the red rice also showed a significant effect on the number of filled pods and the weight of dry filled-pods per clump of mungbean direct-seeded following harvest of the aerobic-irrigated red rice on the raised-beds.

Table 1. Summary of the ANOVA of the impacts of the cultivation techniques of red rice and application of organic wastes to the red rice on growth, yield and yield components of mungbean direct-seeded following the red rice crop grown on raised-beds under aerobic irrigation systems

Measurement variables	p-value of the ANOVA for each source of variation		
	Techniques (T)	Wastes (L)	T*L interaction
Plant height at 56 DAS	0.5128	0.7554	0.6743
Number of trifoliate leaves at 56 DAS	0.3377	0.7041	0.4531
Number of productive branches per clump	0.1846	0.2595	0.2224
Number of filled pods per clump	0.1338	**0.0008**	**0.0442**
Number of unfilled pods per clump	0.0655	**0.0013**	0.0684
Weight of dry filled-pods per clump	**0.0255**	**0.0030**	**0.0291**
Number of grains per clump	**0.0361**	**0.0069**	0.0630
Weight of 100 grains	0.7910	0.3657	0.3744
Dry grain yield per clump	**0.0445**	**0.0030**	0.0520

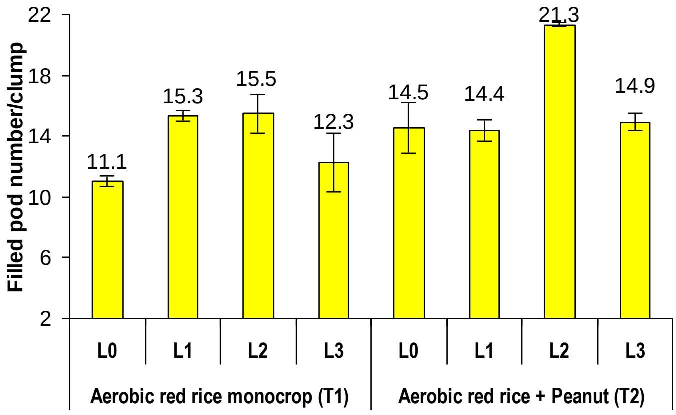

Figure 1. The interaction effect between cultivation techniques of the red rice and application of organic wastes to the red rice on number of filled pods per clump of the mungbean plants direct-seeded following rice plants grown on raised beds under an aerobic irrigation system (error bars are SE)

Based on the patterns of the interaction effects, Figure 1 shows that the number of pods was higher in mungbean plants that were direct-seeded following harvest of the red rice plants intercropped with peanuts grown on the raised-beds receiving rice husk ash application (an average of 21.3 pods per clump) compared to following the monocropped red rice plants, either receiving organic waste application or not, with the lowest average number of filled pods per clump (11.1 pods/clump) found on mungbean plants following monocropped red rice receiving no organic waste application. Inal et al. (2007) stated that intercropping corn plants with peanut plants can increase availability of the nutrients in the rhizosphere of each plant in an intercropping system when compared to the rhizosphere of each plant grown in monocrop. The increase in the number of pods on the mungbean plants along with the application of organic waste cannot be separated from the availability of P and K nutrients in the rice husk ash whose role is quite important in protein formation, helping the respiration and assimilation processes as well as speeding up the flowering process in plants, so that with lots of flowers growing on mungbean grown especially on the raised-beds receiving rice husk ash during the growth of the preceding red rice plants, then those mungbean plants can produce a greater number of filled pods (Lingga and Marsono, 2003).

In relation to dry pod weight per clump, Figure 2 shows similar patterns of interaction with Figure 1, in which the dry pod weight of mungbean direct-seeded following red rice intercropped with peanuts grown on the raised-beds receiving application of rice husk ash was on average higher (14.44 g/clump) than that of mungbean direct-seeded following monocropped red rice either without or with the application of organic wastes, with the lowest average of dry filled-pod weight being on mungbean following monocropped red rice receiving no application of organic wastes (6.74 g/clump). It is suspected that the high pod weight of mungbean on the T2L2 treatment was due to the availability of sufficient nutrients for the reproductive growth of the mungbean plants direct-seeded following the red rice intercropped with peanuts receiving rice husk ash application, when compared with the application of other types of organic wastes, or when compared with mungbean plants direct-seeded following the monocropped red rice. Lu et al. (2019) reported that after intercropping with peanuts there was an increase in the soil available N content, rhizosphere bacteria (rhizobacteria), and an improvement in soil pH, so that it had a positive effect on mungbean direct-seeded following the red rice intercropped with peanuts. In addition, Dulur et al. (2020b) also stated that the growth and yield components of mungbean, which include the number of filled pods, number of grains and grain yield per clump, were significantly higher if they were direct-seeded the red rice plants under aerobic irrigation system intercropped with peanuts compared with following conventional red rice, especially in mungbean plants that received applications of rice husk ash and the mixtures of rice husk ash with cattle manure.

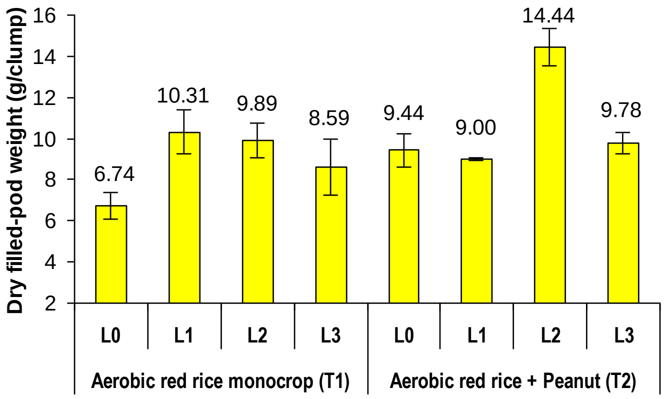

Figure 2. The interaction effect between cultivation techniques of the red rice and application of organic wastes to the red rice on weight of dry filled-pods (g/clump) of the mungbean plants direct-seeded following rice plants grown on raised beds under an aerobic irrigation system (error bars are SE)

In addition, based on the average influence of each factor (the main effects) summarized in Table 2, it can be seen that the data on the yield components of mungbean plants also varies between various organic wastes applied to the previous red rice plants. The number of pods, number of grains, and grain yield per clump of mungbean plants direct-seeded following the aerobic-irrigated red rice intercropped with peanuts (T2) were significantly higher than on those following monocropped red rice. This was thought to be due to the relay-planting of peanuts between double rows of red rice plants, which can increase the availability of nutrients, especially N, in the rhizosphere of the red rice plants intercropped with peanuts compared to monocropped red rice, as has been reported by Chu et al. (2004). In line with this, according to Dulur et al. (2020b), peanut plants are capable of increasing soil N content, due to rhizodeposition of N by peanut root nodules (Fustec et al., 2010) so that mungbean plants direct-seeded following the aerobic-irrigated red rice plants intercropped with peanuts can take advantage of this higher N availability. Rabani et al. (2021) also reported that the number of filled pods, dry pod weight, number of grains, and grain yield per clump of mungbean were higher on mungbean plants direct-seeded following aerobic red rice intercropped with peanuts than following conventional red rice. In addition, according to Lu et al. (2019), young tea plants intercropped with peanuts significantly improve soil conditions such as the availability of exchangeable N, Mg and Ca, when compared to monocrop planting (without intercropping with peanuts).

Table 2. Mean plant height (PH, cm), trifoliate leaf number (TLN, no/clump), productive branches (PB, no/clump), filled-pod number (FPN, no/clump), unfilled-pod number (UFPN, no/clump), dry filled-pod weight (DFPW, g/clump), grain number (GN, no/clump), weight of 100 grains (W100, g), and grain yield per clump (GY, g/clump)

Treatments	Measurement variables																	
	PH (cm)		TLN		PB		FPN		UFPN		DFPW		GN		W100		GY	
T1: monocrop	38.90	a	8.33	a	3.16	a	13.53	a	1.05	a	8.88	b	111.16	b	5.84	a	6.54	b
T2: intercrop	36.78	a	8.75	a	3.69	a	16.30	a	1.15	a	10.66	a	133.43	a	5.82	a	7.81	a
HSD 5%	11.54		1.43		1.08		4.85		0.11		1.24		18.68		0.23		1.19	
L0: No waste	39.63	a	8.17	a	3.12	a	12.80	b	1.01	b	8.09	b	104.06	b	5.61	a	5.88	b
L1: Rice husk	36.61	a	8.50	a	3.06	a	14.86	b	1.13	ab	9.65	ab	121.26	ab	5.86	a	7.15	ab
L2: Husk ash	36.57	a	8.33	a	3.06	a	18.40	a	1.31	a	12.16	a	151.53	a	5.82	a	8.95	a
L3: L2+manure	38.65	a	9.16	a	3.04	a	13.60	b	0.93	b	9.18	b	112.33	b	6.03	a	6.78	b
HSD 5%	7.57		1.96		0.58		2.26		0.16		1.85		24.85		0.49		1.04	

Remarks: Mean values in each column followed by the same letters are not significantly different among levels of a treatment factor

Mungbean plants direct-seeded following red rice plants grown on the raised-beds receiving application of husk ash (L2) showed a significantly higher average of filled pod number, filled pod weight, number of grains, and grain yield per clump when compared to mungbean plants direct-seeded following red rice plants receiving no application of organic wastes (Table 2). This is thought to be due to the effects of rice husk ash applied to the preceding rice plants on the nutrient contents, and it still had a positive influence on the mungbean direct-seeded following red rice plants without tillage. Bakri (2008) states that rice husk ash is an alkaline fertilizer that contains several essential nutrients needed by plants, including around 87-97% silicate, 1% nitrogen, 0.2% phosphorus and 0.58% potassium. Riono and Apriyanto (2020) also reported that the application of rice husk ash had a very significant effect compared to without the application of organic waste, because the Si contained in rice husk ash was able to increase the availability of phosphates by replacing P ions bound by soil components so that P became available for plants direct-seeded following the red rice plants.

5. CONCLUSION

Based on the results of the data analysis, it can be concluded that there was an interaction effect between the cultivation techniques of aerobic-irrigated red rice and the application of organic wastes to the red rice on the number of pods, and dry pod weight per clump of mungbean plants direct-seeded following the red rice, in which the dry pod weight was on average highest (14.44 g/clumps) in mungbean direct-seeded following the aerobic-irrigated red rice plants intercropped with peanuts grown on raised-beds that received husk ash application (T2L2 treatment), and lowest (6.74 g/clump) in mungbean direct-seeded following monocropped red rice without application of organic wastes (T1L0 treatment). In general, intercropping red rice with peanuts significantly increased the dry pod weight, grain number, and grain yield per clump of mungbean plants direct-seeded following monocropped red rice.

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