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Growth and yield of peanut relay-planted between rows of waxy maize as affected by row proportion and mycorrhiza biofertilizer

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Abstract. One reason for low peanut production in Indonesia is unavailability of sufficient land area for peanut cultivation, so additive intercropping is a possible solution. The objective of this study was to investigate whether mycorrhiza biofertilizer and row proportions affect growth and yield of peanut relay-planted between rows of waxy maize under normal plant spacing of maize, by establishing an experiment in Narmada rainfed land from June to August 2017. The treatments were arranged under Split Plot Design, in which the application of mycorrhiza biofertilizer was placed in the main plots (M0= without; M1= with mycorrhiza biofertilizer), whereas the subplots were different row proportions of peanut-maize (R0= monocropped peanut; R1= relay-planting 1 row; R2= relay-planting 2 rows; and R3= relay-planting 3 rows of peanut between two rows of waxy maize). The results indicated that biofertilizer application and row proportions of peanut-maize had an interaction effect on leaf number at 7 weeks, average growth rate of leaf number, and grain yield of peanut per clump but not per plot. However, under mycorrhiza biofertilization relay-planting three peanut rows increased peanut grain yield per m^2, with grain yield average of 1.97 ton/ha or 75.59% of grain yield of the monocropped peanut. Therefore, peanut production can be done between rows of waxy maize of normal population, especially with application of mycorrhiza biofertilizer, which could contribute up to 1.97 ton/ha peanut grain yield in addition to the waxy maize yield.

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1. INTRODUCTION

Among the food crops, peanut is a very important crop required by Indonesian people. Peanut plants produce highly nutritious grains, which are very good for human nutrition and health. According to the USDA National Nutrient Database for Standard Reference cited by Davis and Dean (2016), the raw peanut kernels contain up to 49.2% total lipid, 25.8% protein, 16.1% carbohydrates, 8.5% total dietary fiber, and 4.7% total sugars. In addition, the lipid content of peanut grains is high in unsaturated fatty acids, which are good for cardiovascular health. According to Çiftçi and Suna (2022), cardiovascular disease risk factors can be reduced by frequent consumption of peanut. Peanut can be consumed as boiled or fried or roasted grains (Sumarno, 2015) or as primary ingredients in other foods such as peanut butter, snack bars, and other finished products (Davis & Dean, 2016).

Due to it nutritious grains, especially the high contents of fat and protein, peanut grains can be used as a cheap alternative to meat. This resulted in increasing needs for peanut in Indonesia as the population density increased while domestic production cannot meet the increasing needs for peanut. Therefore, import has to be done in order to meet domestic needs for peanut, and the volume of peanut import by Indonesia has increased since 1990 (Sumarno, 2015). In order to reduce the volume of peanut import, the total production needs to be increased, either by increasing harvested areas of peanut or increasing the productivity, which is still very low in Indonesia. Based on data in 2008, the highest average productivity of peanut was 3.84 t/ha in the US, followed by 3.56 t/ha in China, 3.17 t/ha in Egypt, 2.77 t/ha in Argentina, and 2.62 t/ha in Brazil, which were five countries with the five highest levels of peanut productivity, while in the same year, peanut productivity in Indonesia was only 1.67 t/ha (Valentine, 2016). This means that peanut productivity still can be increased in Indonesia.

The low production of peanut in Indonesia was partly due to the unavailability of sufficient areas for cultivation of peanut. In the irrigated rice growing areas, peanut is normally grown in the dry season as a rotation crop with rice, either after the rainy season rice (the first rice cropping) or after the second rice cropping. Peanut is also grown in rainfed dryland but mostly only during the rainy season (Sumarno, 2015). However, both in the irrigated areas and rainfed dryland, there are competing interests between growing peanut and maize, and based on the food crop statistics (https://bps.go.id), peanut is only the fourth most important food crops after rice, maize and soybean.

Due to the competing interest for cultivation of maize instead of peanut, partly because of much higher grain yield of maize than peanut, in addition to the more difficulties of getting good quality seeds of peanut than maize, the another way of producing maize and peanut is by intercropping peanut in additive series with maize. By inserting two peanut rows between two rows of open pollinated maize, some varieties of peanuts could produce up to 50% grains under additive intercropping compared with under monocropping system based on grain yield per clump (Wangiyana et al., 2018). In an additive intercropping of mungbean or soybean with waxy maize of "Bima" local variety, increasing number of rows relay-planted between rows of the waxy maize could increase grain yield of mungbean or soybean per unit of land area, although grain yield per clump was reduced. In this experiment, however, increasing number of soybean rows or mungbean rows relay-planted between two rows of waxy maize could increase the waxy maize grain yield (Wangiyana et al., 2020).

In addition to increasing the population of legume crops in intercropping with maize, mycorrhiza biofertilization could also increase yield of the legume crop. Several varieties of mycorrhiza-biofertilized peanut grown between rows of an open pollinated maize also increased grain yield of several peanut varieties (Wangiyana et al., 2018). Yield of peanut of Bison and Hypoma-1 varieties intercropped with black rice in a replacement series with 2:2 row proportion could also be increased by mycorrhiza biofertilizer application compared with no biofertilizer application (Zainab & Wangiyana, 2021). Additive intercropping with peanut also increased growth and yield of sweet corn under mycorrhiza biofertilization (Wangiyana et al., 2021a).

In an intercropping system, close proximity of the plants between legumes and non-legumes also reported to increase N transfer between legume and non-legume crops, such as under sorghum and soybean intercropping system (Fujita et al., 1990). When there was mycorrhizal symbiosis involved in legume and non-legume intercropping, arbuscular mycorrhizal fungi (AMF) inoculation to both crops could increase nutrient transfer between roots of both crops, such as fixed-N transfer from the legumes to non-legumes (Bethlenfalvay et al., 1991; Meng et al., 2015).

The objective of this study was to investigate whether mycorrhiza biofertilizer and row proportions affect growth and yield of peanut relay-intercropped between waxy maize rows in an additive intercropping system with different row proportions of peanut to maize rows under normal plant spacing of the waxy maize plants.

2. MATERIALS AND METHOD

In this study the experiment was established on a piece of rainfed land in Narmada, West Lombok, Indonesia, from June to August 2017, which was during the 2017 dry season. Peanut of Hypoma-1 variety, obtained from the Research Center of Legume and Root Crops (Balitkabi) in Malang, Indonesia. Rows of the peanut were relay-planted between rows of waxy maize of “Bima” local variety. The mycorrhiza biofertilizer used was the one produced by “BPPT” Serpong, Indonesia, under the trade mark “Technofert”, which contains mixed AMF species.

2.1. Design of the experiments

The two treatment factors were arranged in a Split Plot experiment consisting of three blocks functioning as the replications. The main plot factor was mycorrhiza biofertilizer application, consisting of two treatment levels (M0= without; M1= with mycorrhiza biofertilizer applied in the planting holes of peanut seeds), and the subplot factor was row proportion of peanut-maize, consisting of different row proportions of peanut-maize or number of peanut rows inserted between two rows of waxy maize, with four treatment levels (R0= monocropped peanut; R1= relay-planting 1 row of peanut; R2= relay-planting 2 rows of peanut; and R3= relay-planting 3 peanut rows between two rows of waxy maize). The monocropped peanuts were dibbled under plant spacing of 25 cm x 20 cm, while those relay-planted between rows of waxy maize, the between-row distances depended on the treatments.

2.2. Implementation of the experiment

Land preparation included once plowing and once harrowing followed with plotting and building up raised-beds of 3 m x 1.2 m size as explained in Wangiyana et al. (2021b). The waxy maize seeds were dibbled under plant spacing of 75 cm x 20 cm, which then tinned at two weeks after seeding to leave only one maize plant to grow per planting hole. Peanut seeds were dibbled between rows of the waxy maize at 21 days after seeding (DAS) of waxy maize seeds, with planting distance of 20 cm within rows and row distances depending on the number of peanut rows relay-planted between two rows of the waxy maize (37.5 cm between waxy maize and peanut rows under R1; 25 cm between peanut and/or waxy maize rows under R2; and 18.75 cm between peanut and/or waxy maize rows under R3 treatment). Under M1 treatments, the mycorrhiza biofertilizer was applied into the base of the planting hole (5 g per planting hole) both for waxy maize and peanut, the biofertilizer covered with soil and seeds were placed on that soil, and lastly the seeds were covered with a thin layer of soil.

Crop maintenance after planting the seeds consisted of fertilizer application, weeding, and pesticide spraying to protect the plants from insect attack, especially plant hoppers, and stem and cob borers in the maize plants by spraying systemic insecticides. The waxy maize plants were fertilized with NPK (15-15-15) fertilizer as the basal fertilizer with a dose of 300 kg/ha followed with application of Urea (45% N) fertilizer, while peanut plants were fertilized only with NPK (15-15-15) fertilizer as the basal fertilizer with a dose of 200 kg/ha. The procedures of application of those fertilizers and other maintenance are as explained in Wangiyana et al. (2021b).

2.3. Observation variables and data analysis

Peanut plant height was measured and leaf and branch number per clump were counted every week from 1-7 weeks after seeding (WAS) for use to calculate the AGR (average growth rates) of height and number of leaves and branches of the peanut plants, based on the formula used by Pedersen and Lauer (2004). The number of root nodules was counted, and grain number and yield per clump as well as the weight of 100 grains were recorded after harvest. The partial land equivalent ratio (LER) was calculated using the average grain yield of the monocropped peanut as the denominator in the equation, then multiplied by 100%, in which p-LER (partial LER) was calculated using equation:
p-LER = percentage of grain yield of intercrop per plot divided by grain yield of monocrop per plot.

For analyzing the data, the analysis of variance (ANOVA) and Tukey's HSD were used, all were based on the significance level of 5%. The analysis was carried out using CoStat for Windows ver. 6.303. In addition, MS Excel for Windows was also used analyzed the correlation coefficients to find the strength of association between observation variables.

3. RESULT AND DISCUSSION (2200-3000 WORDS)

The results of ANOVA indicated that the significant interaction effects only occurred on peanut leaf number and AGR of leaf number (Table 1), and on grain yield per clump (Table 2).

Table 1. Main effects of the treatment factors on growth variables of peanut

Treatments	**Plant height (cm) at 7 WAS**	**Leaf number per clump at 7 WAS**	**Branch number per clump at 7 WAS**	**AGR leaf number**	**AGR branch number**	**Nodule number per clump**	**Nodule number per m^2**
R0	52.92 b	54.38 a	6.67 a	5.80 a	0.63 a	158.50 a	2641.67 a
R1	56.54 ab	52.33 a	5.50 a	5.83 a	0.43 a	151.58 a	757.92 c
R2	58.83 a	52.04 a	5.50 a	5.96 a	0.48 a	133.71 a	1337.08 bc
R3	60.79 a	53.46 a	5.71 a	5.81 a	0.40 a	131.25 a	1968.75 ab
HSD	4.69	ns	ns	ns	ns	ns	845.65
M0	55.40 b	51.31 b	5.77 a	5.29 b	0.37 b	137.35 a	1589.93 a
M1	59.15 a	54.79 a	5.92 a	6.41 a	0.59 a	150.17 a	1762.78 a
HSD	2.45	2.35	ns	0.36	0.19	ns	441.17
Interaction	ns	s	ns	s	ns	ns	ns

Remarks: WAS = weeks after seeding; s = statistically significant ($p<0.05$); ns = non-significant ANOVA; mean values sharing no same letters are significantly different

Based on the mean value and standard error of each treatment combination, the patterns of the interaction effects are different among those variables. In the monocropped peanut (R0), the average leaf number and its AGR were highest on peanut supplied with mycorrhiza biofertilizer and they are lowest on the non-biofertilized peanut plants. Although there were significant differences in the AGR of leaf number between biofertilized and non-biofertilized peanut plants (Fig. 2), the average numbers of leaves at 7 WAS were not significantly different between biofertilized and non-biofertilized peanut plants, which were relay-intercropped between waxy maize rows (Fig. 1). However, grain yield of peanut per clump was significantly higher on the biofertilized than on those that were not biofertilized, except for the peanut plants grown under monocropped system (R0). In addition, grain yield of peanut per clump was highest on the biofertilized peanut that was relay-intercropped only one row (R1) between two rows of waxy maize plants (Fig. 3).

Table 2. Main effects of the treatment factors on the yield variables of peanut

Treatments	Grain number per clump	Grain yield per clump (g)	Weight of 100 grains (g)	Grain number per m^2	Grain yield per m^2 (g/m^2)	Grain yield (t/ha)	p-LER of grain yield (%)
R0	29.04 a	15.33 a	53.08 b	484.03 a	256.27 a	2.56 a	-
R1	26.08 b	15.00 ab	57.37 ab	130.42 d	74.50 d	0.75 d	29.03 c
R2	24.04 b	13.88 b	57.80 ab	240.42 c	138.76 c	1.39 c	54.09 b
R3	20.33 c	12.12 c	59.67 a	305.00 b	181.70 b	1.82 b	70.83 a
HSD	2.49	1.13	5.23	28.64	15.79	0.16	2.69
M0	22.77 b	13.06 b	57.70 a	268.54 b	153.25 b	1.53 b	47.69 b
M1	26.98 a	15.10 a	56.26 a	311.39 a	172.37 a	1.72 a	54.94 a
HSD	1.30	0.59	ns	14.94	8.24	0.08	3.24
Interaction	ns	s	ns	ns	ns	ns	ns

Remarks: WAS = weeks after seeding; s = statistically significant ($p<0.05$); ns = non-significant ANOVA; mean values sharing no same letters are significantly different

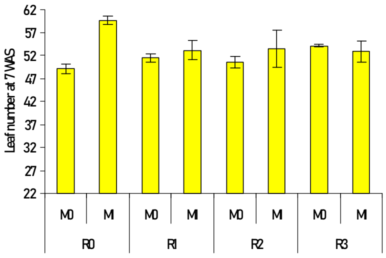

Fig. 1. Leaf number per clump (Mean ± SE) of peanut as affected by interaction between biofertilization and relay-planting

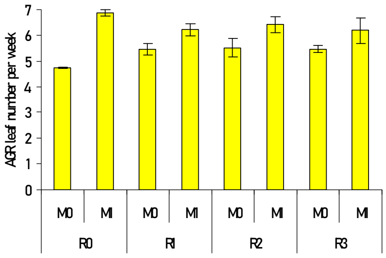

Fig. 2. AGR of leaf number (Mean ± SE) of peanut as affected by interaction between biofertilization and relay-planting

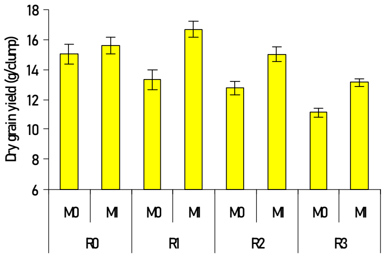

Fig. 3. Grain yield per clump (Mean ± SE) of peanut as affected by interaction between biofertilization and relay-planting

In terms of grain yield of peanut plants per clump in Fig. 3, it appears that the yield differences were resulted from the magnitudes of the inter- and intra-specific competitions between plants. In the monocropped peanut plants (R0), plant spacing was 25 x 20 cm, but in the intercropped peanut plants with relay-planting of 1 row (R1), plant spacing was 37.5 cm between peanut and waxy maize rows, while in R2 and R3, the distances were 25 cm and 18.75 cm respectively. However, in the R2 and R3 conditions, the inter- and intra-specific competitions could be more serious because peanut plants not only competed with the adjacent peanut plants but also competed with waxy maize plants. Therefore, it is logical that grain yield per clump of peanut plants was lower as the number of peanut rows relay-planted between rows of waxy maize plants was higher (R2 and R3). However, fertilization of both peanut and waxy maize plants with mycorrhiza biofertilizer was found to significantly increase grain yield of the peanut plants per clump under intercropping with waxy maize (Fig. 3).

Previous study reported that various nutrients were more available in the rhizosphere of maize or peanut under intercropping than in maize or peanut rhizosphere in manocropping system, and these conditions resulted in higher nutrient concentration in the shoots of intercropped than monocropped plants. The concentration of N, P and K, and some micronutrients such as Fe, Zn, and Mn as well as chlorophyll contents were found to be higher in the shoot of peanut under intercropping with maize than under monocropping system (Inal et al., 2007). Subhashini (2016) also found that levels of uptake of various nutrients, including P, Zn, Cu, Mn and Fe, as well as biomass and pod weight were higher in mycorrhiza inoculated peanut than in the uninoculated plants, either under sterilized or non-sterilized soil. Involvement of mycorrhizal fungi in intercropping can facilitate nutrient transfer between the intercrops (Bethlenvalvay et al., 1991; Meng et al., 2015). Increased growth and yield of peanut-relay planted between rows of maize applied with mycorrhiza biofertilizer can be attributed to the stimulation of macro- and micro-nutrients uptake and translocation of various nutrients (Rouphael et al., 2015).

Application of mycorrhiza biofertilizer enhanced the concentration of nutrients which leads to increased photosynthate production, hence increased in number of peanut leaf per clump (Table 1) and average growth rate of leaf number (Fig. 2); and increased biomass accumulation (Mitra et al., 2019) evident in the grain number per peanut pod (Table 2). Silva et al. (2017) reported that the nutrient absorption of peanut peaks during the reproductive stage, therefore biofertilization plays an important role in grain yield formation. Nodulation in peanut in this study, however, was not significantly affected by the application of mycorrhiza biofertilizer, although there was a tendency for nodule number to be higher in roots of peanut supplied with mycorrhiza biofertilizer than in those without application of biofertilizer (Table 1). However, previous study found that application of mycorrhiza biofertilizer resulted in significantly higher nodule number in roots of the “55-437” and “69-101” peanut cultivars but in the “Fleur 11” cultivar it was not significantly different (Godar et al., 2010).

In addition, it can also be seen from Table 3 that grain yield per m^2 (GYM) was highly correlated with nodule number per m^2 (NODM), with an R^2 of 72.93% (p-value < 0.001). Nodule number per m^2 (NODM) was also highly correlated with grain number per m^2 (GNM) with an R^2 of 71.91% (p-value < 0.001). In relation to grain yield, it means that 72.93% of variation in grain yield per m^2 (GYM) was determined by nodule number in the roots of peanut plants per m^2. According to Sinclair and de Wit (1975), the rates of photosynthate partition to the developing seeds of legume crops during their seed-filling stage and their grain production quantity are highly dependent on nitrogen supplying capacity of the legume crops, and if N supplying capacity of the root systems is less than total N required for seed filling, then the plants will remobilize N from the vegetative parts of the plants, especially leaves, to the growing seeds, which in turn will fasten leaf senescence process. This could be the reason for the highly significant correlation between nodule number per m^2 and grain yield per m^2.

In terms of the main effects, application of mycorrhiza biofertilizer significantly increased growth variables, including plant height and leaf number per clump at 7 WAS, and AGR of leaf number and branch number (Table 1), as well as increased yield components of peanut relay-planted between rows of waxy maize plants, except for the weight of 100 dry grains (Table 2). The significantly increased grain yield of peanut per unit of land area (per m^2 or per ha) by fertilization with mycorrhiza biofertilizer seems to be due to an increase in grain number, which was also significantly increased by application of mycorrhiza biofertilizer (Table 2). Since the weight of 100 grains was not significantly different between treatments with mycorrhiza biofertilizer, then grain yield, which is approximately the product of grain number and weight of 100 grains would also be increased by application of mycorrhiza biofertilizer. The result of regression analysis showed the highest correlation coefficient (Table 3) between grain yield per m^2 (GYM) and grain number per m^2 (GNM), with a regression equation of GYM = 15.588 + 0.508 GNM (R^2 = 97.28%, p<0.001), which means that 97.28% of variation in grain yield per m^2 was determined by grain number per m^2.

Table 3. Summary of correlation coefficients and p-values between plant height at 6 (PH6) and 7 WAS (PH7), leaf number at 6 (LN6) and 7 WAS (LN7), branch number at 6 (BN6) and 7 WAS (BN7), nodules per clump (NODC) and per m^2 (NODM), grain yield per clump (GYC) and per m^2 (GYM), and grain number per clump (GNC) and per m^2 (GNM)

Correlation	PH6	PH7	LN6	LN7	BN6	BN7	NODC	NODM	GYC	GNC	GNM
PH7	0.929										
p-value	**0.000**										
LN6	-0.231	-0.234									
p-value	0.278	0.272									
LN7	0.089	0.091	0.736								
p-value	0.679	0.672	**0.000**								
BN6	-0.409	-0.361	0.662	0.531							
p-value	**0.047**	0.083	**0.000**	**0.008**							
BN7	-0.215	-0.113	0.622	0.524	0.815						
p-value	0.312	0.600	**0.001**	**0.009**	**0.000**						
NODC	-0.210	-0.199	-0.026	0.023	0.045	0.022					
p-value	0.324	0.352	0.902	0.915	0.835	0.919					
NODM	-0.258	-0.191	0.180	0.173	0.350	0.385	0.512				
p-value	0.224	0.372	0.401	0.419	0.094	0.063	**0.011**				
GYC	-0.185	-0.162	0.110	0.314	0.355	0.360	0.316	0.036			
p-value	0.388	0.448	0.608	0.135	0.089	0.084	0.133	0.867			
GNC	-0.261	-0.225	0.230	0.417	0.398	0.443	0.318	0.188	0.923		
p-value	0.217	0.290	0.281	**0.043**	0.054	**0.030**	0.130	0.379	**0.000**		
GNM	-0.321	-0.249	0.284	0.331	0.459	0.537	0.134	0.848	0.195	0.390	
p-value	0.126	0.241	0.178	0.115	**0.024**	**0.007**	0.534	**0.000**	0.361	0.059	
GYM	-0.280	-0.212	0.256	0.284	0.455	0.518	0.102	0.854	0.138	0.293	0.986
p-value	0.185	0.319	0.227	0.179	**0.026**	**0.010**	0.635	**0.000**	0.520	0.165	**0.000**

In relation to the partial LER of peanut grain yield per plot, it can be seen from Table 3 that increasing the proportion of rows or number of rows of peanut relay-planted between two rows of waxy maize, on average, significantly increase partial LER of peanut grain yield per plot, i.e. 29.03% in R1, 54.09% in R2, and 70.83% in R3, which means that relay planting 3 rows of peanut between two rows of waxy maize plants contributed an additional 70.83% of peanut grains compared with grain yield of the monocropped peanut, in addition to grain yield of the waxy maize. Therefore, when cultivating waxy maize of Bima local variety, instead of leaving the blank area of the 75 cm inter-row land between waxy maize rows, which is potentially covered with weeds, it is beneficially to use that land for growing peanut, especially when accompanied with application of mycorrhiza biofertilizer. It can also be seen from Table 4 that application of mycorrhiza biofertilizer could significantly increase the partial LER of peanut grain yield per plot. In addition, relay-planting peanut between rows of maize significantly increased grain yield of waxy or hybrid maize (Wangiyana et al., 2021a), or significantly increased growth and fresh cob weight of sweet corn (Wangiyana et al., 2021b).

Thus, it appears that the negative effect of competition in the experimental set-up with many rows of peanut where plants compete for nutrients, water, and space, is compensated by biofertilization. The AMF component in the mycorrhiza biofertilizer could improve tolerance of plants to environmental stresses by bringing about several changes in their morphological or physiological traits (Bhardwaj et al., 2014). In Hypoma-1 peanut variety, application of mycorrhiza biofertilizer resulted in increased grain yield even when grown under multiple peanut rows. Increased number of pods per peanut was also observed. Other than uptake of nutrients, AMF could also increase water uptake, water holding capacity and soil quality (Kuila and Ghosh, 2022). Bi and Zhou (2021) also reported that peanut plants inoculated with AMF produced significantly higher plant height, total leaf area, and improved canopy structure, and these all resulted in higher photosynthetic rates, above-ground and root biomass, and yield of the AMF inoculated plants compared with the non-inoculated peanut plants.

Table 4. Effects of number of rows of peanut relay planted between two rows of waxy maize on peanut grain yield per m^2 and partial LER of peanut grain yield per plot in percent

Relay-planting treatments:	Grain yield (g/m^2)		Partial LER of grain yield per plot (%)				
	M0	M1	M0-Mean	SE	M1-Mean	SE	Average
T1: relay-planting 1 row of peanut	66.6	82.4	26.42	± 1.34	31.64	± 1.40	29.03 c
T2: relay-planting 2 rows of peanut	127.6	150.0	50.58	± 1.68	57.60	± 1.83	54.09 b
T3: relay-planting 3 rows of peanut	166.6	196.8	66.06	± 1.88	75.59	± 1.54	70.83 a

Based on these data, the blank space of 75 cm width between rows of waxy maize can be utilized to produce peanut by relay-planting 3 rows of peanut between two rows of waxy maize plants (R3), accompanied with application of mycorrhiza biofertilizer (M1), and this could produce peanut grain yield up to 1.97 ton/ha or 75.59% of grain yield of the monocropped peanut. This demonstrates an efficient cropping system which could fix nitrogen and potentially transfer it to non-nodulated companion crops, such as in those reported previously (Inal et al., 2007; Wangiyana et al., 2021a).

4. CONCLUSION

Peanut can be produced by relay-planting it between rows of waxy maize, and increased grain yield per plot can be achieved by increasing row proportion of peanut to maize, i.e. increasing number peanut rows to be inserted between rows of waxy maize plants. Mycorrhiza biofertilization of waxy maize and peanut could further increase grain yield of peanut, and relay-planting three peanut rows between waxy maize rows could contribute to peanut grain yield up to 1.97 ton/ha (or 75.59% of grain yield of the monocropped peanut).

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AUTHORS' CONTRIBUTIONS

Author1 designed the experiment, did the crop field sampling, finished data analysis and presentation of the graphs, and finished and submitted the manuscript. Author2 helped in measurement of crop growth and yield components. Author3 helped in drafting the discussion and the Introduction of this article.

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