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Yield Comparison of Groundnut (*Arachis hypogaea* L) and Corn (*Zea mays* L) Under Sole and Multiple Cropping Systems

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Abstract Multiple cropping is often more efficient in land use than sole cropping; however, the yield of each crop can be lower in multiple cropping than in sole cropping. This study evaluated the effect of multiple cropping on the yield of corn and groundnut. Seeds of groundnut and corn were sown simultaneously. Corn seeds were planted 1 m between rows, and groundnut seeds were sown between corn rows for one and two rows. The one-way ANOVA shows that yield of corn was not affected by multiple cropping, while the yield of groundnut in multiple cropping at <71 g/plant was significantly lower than in sole cropping at 119 g/plant. Morpho-agronomic traits (plant height, number of leaves, circumference of corn stalk, biomass and length and circumference of corncob) between sole and multiple cropping in corn were not significant. However, groundnut grown under multiple cropping was significantly taller and produced more leaves than under sole cropping. The number of leaves had a positive correlation with the yield in corn (0.76) but had a negative correlation with the yield in groundnut (-0.72). The land equivalent ratio in multiple cropping was between 1.5 and 3.0, indicating that multiple cropping is more land-use efficient than sole cropping. These findings demonstrate that multiple cropping between corn and groundnut is efficient for using the land, and groundnut yield compensates for this multiple cropping treatment.

Keywords Yield, Multiple Cropping, Sole Cropping, Morpho-agronomic Traits, Land Equivalent Ratio

1. Introduction

The population in Indonesia is projected to be almost 3 million people in 2030, but the number of agricultural lands is decreasing [1]. The rise in population can result in an increase in food consumption but in limited agricultural areas because most agricultural lands are converted into housing and industry [1]. Therefore, increasing land use efficiency by growing more than one crop in the same period is essential to food security.

Corn (*Zea mays* L.) is one of the main crops in Indonesia [2,3]. Corn is mainly produced for human consumption, accounting for 71.7% of national production, and for animal feed, food industry and export, accounting for 15.5%, 0.8% and 0.1%, respectively [4]. The production of corn increased from 6 million tons in 1993 to 19 million tons in 2015 [5]. However, more than this yield increase is required for consumption because the population is projected to reach 3 billion in 2030 [1].

Groundnut (*Arachis hypogaea* L.) is one of the main legumes grown in Indonesia [6,7]. Groundnut is often processed as a side dish in traditional food [7]. According to Zulchi et al. (2020), groundnut has the ability to fix nitrogen in the soil through its root nodules. Groundnut leaves are also used for animal feed [8]. However, the production and areas planted to groundnut have decreased in the last ten years. In Lampung province, for example, the total area planted for groundnut was 3,764 ha in 2015, but the planted area was reduced to 3,246 ha in 2017 [9]. Therefore, optimum land utilisation, such as multi-cropping, is crucial to support demand for groundnut consumption.

Legumes such as groundnut are often planted under multi-cropping with cereal grain crops such as corn and sorghum [10-12]. Legumes were often intercropped with cereal grain crops due to their physiological characteristics, where cereal grain crops use C4 photosynthetic pathway and legume crops use C3 photosynthetic pathway [13,14].

Nitrogen, as a result of a symbiosis between legumes and rhizobium, can be transferred directly from legume crops to cereal crops and/or transferred indirectly through Vesicular Arbuscular Mycorrhiza (VAM) fungi associated with roots of legume and cereal crops [14,15]. The nitrogen transferred from legume crops to cereal crops can result in a higher yield of cereal crops under multi cropping than that of cereal crops under sole cropping [11].

Land equivalent ratio is commonly used to justify the yield advantage of multi cropping compared to single cropping [11,12,14]. Multi cropping is identified as beneficial (crop yield in multi cropping is higher than crop yield in single cropping) when the value of land equivalent ratio is more than 1.0 [11,12,16,17]. Wibisana et al. (2017) [11] demonstrated that multi cropping between corn and groundnut is more beneficial than single cropping because the value of land equivalent ratio was 1.6. Ikeh et al. (2012) [17] reported higher land equivalent ratios of above one (1) when white yam was intercropped with melon.

Giving the information about multiple cropping has positive impacts on crop production. This study was designed to investigate three questions: (1) Is the yield of corn and groundnut in multiple cropping higher than in sole cropping? (2) Is there any correlation between the yield of corn and groundnut with morpho-agronomic traits? and (3) Are multiple cropping systems more efficient than sole cropping?

2. Materials and Methods

The experiment was conducted at Gunung Gede experimental field, School of Vocational Studies, IPB University, located at Babakan, Bogor, from 23 August 2022 to 22 November 2022.

The experiment consisted of four treatments in three replicates (12 plots) with a size of 3 m × 3 m (9 m^2) in each plot. The entire experiment size was 108 m^2, and each plot was separated by fallow land with a width of 0.3 m. The first and second treatments were sole cropping of corn (*Zea mays* L. *Saccharata* Sturt) (T1) and groundnut (T2). The third and fourth treatments were multi cropping systems with one row of groundnut between corn rows (T3) and two rows of groundnut between corn rows (T4).

2.1. Land Preparation

The plots were plowed, harrowed and ridged two weeks before planting at a depth of 0.3 m below the soil surface. Dolomite and cow manure were applied to each plot one week before sowing. Dolomite and cow manure doses were 2 t ha^{-1} and 20 t ha^{-1}, respectively, for all treatments.

2.2. Planting

The plant spacing of corn in sole cropping was the same as in multiple cropping (T1, T2, T3 and T4) at 1 m between rows and 0.2 m within rows. The population of corn in T1 was 45 crops (3 crops between rows and 15 crops within rows). The plant spacing of sole cropping groundnut (T2) was 0.5 m between rows and 0.2 m within rows. The population of groundnut in T2 was 90 crops (6 crops between rows and 15 crops within rows). The plant spacing of one groundnut row between corn rows (T3) was 0.5 m from corn rows, whereas the plant spacing of two groundnut rows between corn rows (T4) was 0.25 m from corn rows. The plant spacing within the groundnut row was 0.2 m for multi cropping treatments (T3 and T4). The population of corn in T3 and T4 was 45 crops (three crops between rows and 15 crops within rows). The population of groundnut in T3 was 30 crops (2 crops between rows and 15 crops within rows) and the population of groundnut in T4 was 90 crops (6 crops between rows and 15 crops within rows). Two seeds of groundnut and corn were sown for each planting hole and then thinned out to one crop for each. Soil mounding was applied four weeks after sowing.

2.3. Fertiliser Application

Fertiliser application for single and multiple cropping of corn (T1, T3 and T4) was 180 g $plot^{-1}$, 180 g $plot^{-1}$, and 90 g $plot^{-1}$ for urea (N 46%), SP-36 (P_2O_5 36%), and KCl (K_2O 60%), respectively. The fertiliser of urea, SP-36 and KCl was applied at 90 g $plot^{-1}$, 180 g $plot^{-1}$, and 90 during sowing. The remaining urea at 90 g $plot^{-1}$ was applied four weeks after sowing.

The fertiliser dose for groundnut sole cropping (T2) was 90 g $plot^{-1}$, 180 g $plot^{-1}$ and 135 g $plot^{-1}$ for urea, SP-36 and KCl, respectively, at sowing.

2.4. Measurements

Ten plant samples, excluding border crops, from each net plot were randomly selected for data collection, except for border crops. The ten samples were used with a percentage of more than 10% of each crop population in each net plot. Corns were studied for their plant height, number of leaves and circumference of corn stalks one week before harvest. The length of the corncob, fresh weight of above-ground biomass, yield (fresh weight of corncob) and circumference of the corncob were recorded at harvest. Groundnuts were observed for plant height, number of leaves and stem circumference one week before harvest, whereas yield (fresh weight of unpeeled groundnut), the number of filled pods and fresh biomass was recorded at harvest. The corn and groundnut were harvested 100 days after sowing at a growth stage of R5 [18] for corn and at a growth stage of R7 [19] for groundnut.

The yield of groundnut (fresh weight of unpeeled groundnut) and corn (fresh weight of corncob) was converted into kg ha^{-1}. The land equivalent ratio was then calculated using the yield ratio. The equation for land equivalent ratio is described below [11,12]:

$$\text{Land equivalent ratio} = P1/M1 + P2/M2 \quad (1)$$

Note:

P1 = the mean of corncob yield in multiple cropping
P2 = the mean of groundnut yield in multiple cropping
M1 = the mean of corn yield in sole cropping
M2 = the mean of groundnut yield in sole cropping

2.5. Statistical Analysis

The data from each plot were derived from the mean of 10 samples. The data wers then analysed by analysis of variance (ANOVA) with a randomized complete block design (RCBD) replicated three times. Multiple comparison (Tukey HSD) was used to test for significant differences between treatments. Data normalisation ($W > 0.05$) was carried out before testing the correlation (Pearson Correlation) between morphological traits and yield. R-studio version 4.2.2 was used to identify the significant effect, where significant differences were tested at $p = 0.05$.

3. Results

3.1. Yield of Corn among Treatments

The application of groundnut in between corn rows does not significantly increase the corn yield (Figure 1).

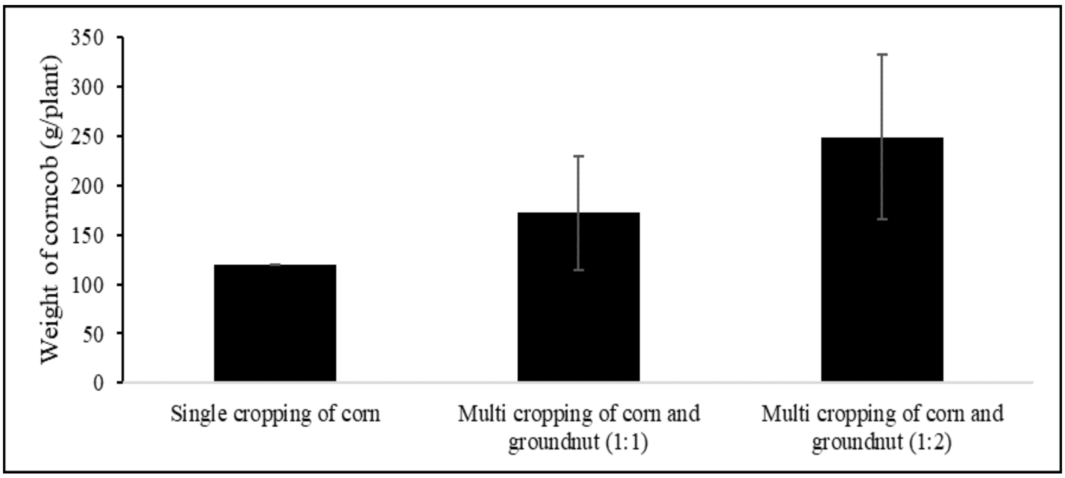

Figure 1. The weight of corncob under sole cropping and multiple cropping with groundnut. The multiple cropping was applied by growing groundnut in between corn rows. The application of groundnut was one row in between corn rows for application of 1:1 (T3) and two rows in between corn rows for application of 1:2 (T4). The weight of the corncob was the rate of fresh harvest of corncob in the net plot 100 days after sowing

3.2. The Response of Corn Morpho-Agronomic Traits under Multiple Cropping with Groundnut

One-way ANOVA shows no significant effect of sowing groundnut between corn rows on the growth of corn. The plant height, number of leaves, stem circumference, length of corn cob, fresh weight biomass and circumference of corn cob were not significantly different (P>0.05) between sole cropping and multiple cropping (Table 1).

Pearson correlation shows that yield has only a significant correlation with the number of leaves at 0.76 (Table 2). The correlation is positive; therefore, many leaves can produce a high corn yield. Other morpho-agronomic traits, including plant height, the circumference of the corn stalk, length of corn cob, fresh weight of above-ground biomass and circumference of corn cob are not significantly correlated with yield.

The circumference of the corn stalk significantly correlates with plant height with a correlation value of -0.88 (Table 2). This positive correlation means that a tall corn plant tends to develop a wide stalk.

Table 1. Multiple comparisons (Tukey HSD) of cropping treatments on corn of plant height (mm), number of leaves, circumference of corn stalk (mm), the length of corncob (mm), fresh weight of above ground biomass (g/plant) and circumference of corncob (mm) by one-way ANOVA

Treatment	Plant height (mm)	Number of leaves	Circumference of corn stalk (mm)	Length of corncob (mm)	Fresh weight of above ground biomass (g)	Circumference of corncob (mm)
Corn	1870 ± 84	11.7 ± 0.5	1.8 ± 0.2	167 ± 26	309.0 ± 91.0	131.5 ± 0.1
Corn Groundnut (1:1)	1568 ± 146	11.7 ± 2.6	2.1 ± 0.1	166 ± 18	251.5 ± 95.0	133.5 ± 2.5
Corn Groundnut (1:2)	1763 ± 256	19.1 ± 3.5	2.1 ± 0.2	157 ± 14	436.3 ± 127.6	144.7 ± 14.5
F probability (*P*)	Ns	Ns	Ns	Ns	Ns	Ns

Note: The differences between treatments were not significant (P = 0.05). Data are means followed by the error of three replicates. The traits of plant height (mm), number of leaves and stem circumferences (mm) were recorded one week before harvest, whereas the number of pods and fresh biomass (g) were recorded during harvest.

Ns= non-significant

Corn Groundnut (1:1) = one row of groundnut in between corn rows (T3)

Corn Groundnut (1:2) = two rows of groundnut in between corn rows (T4)

Table 2. Pearson correlation (r) between morpho-agronomic traits from corn cropping treatments – plant height (mm), number of leaves, circumference of corn stalk (mm), the length of corn cob (mm), fresh weight of above ground biomass (g/plant), circumference of corn cob (mm) and yield (g/plant)

	Plant height (mm)	Number of leaves	Circumference of corn stalk (mm)	Length of corn cob (mm)	Fresh weight of above ground biomass (g plant^{-1})	Circumference of corn cob (mm)
Number of leaves	0.56					
Circumference of corn stalk (mm)	0.88**	-0.23				
Length of corn cob (mm)	-0.09	-0.14	0.03			
Fresh weight of above ground biomass (g plant^{-1})	0.39	0.53	-0.08	-0.01		
Circumference of corncob (mm)	-0.34	0.04	0.39	-0.04	-0.39	
Yield (g plant^{-1})	0.22	0.76*	0.11	-0.56	0.45	-0.05

Note: The traits of plant height, number of leaves and circumference of corn stalk were collected one week before harvest (reproductive stage of R4) from a total of corn net plots (n = 9). The length of corn cob, fresh weight of above ground biomass, circumference of corn cob and yield were collected at harvest.

*p < 0.05; **p < 0.01; ***p < 0.001.

3.3. Yield of Groundnut among Treatments

The yield of groundnut (fresh weight of unpeeled groundnut) reduces significantly when the groundnut is grown under multi cropping with corn (Figure 2). The mean yield per plant reduces from 119.2 grams to 67.5 grams for the treatment of multiple cropping of corn and groundnut at a ratio of 1:1 (T3) and to 70.6 grams for the treatment of multiple cropping of corn and groundnut at a ratio of 1:2 (T4). The yield of groundnut between multiple cropping at a ratio of 1:1 and 1:2 does not differ significantly at 67.5 and 70.6 grams per plant, respectively (Figure 2).

3.4. The Response of Groundnut Morpho-Agronomic Traits under Multiple Cropping with Corn

The treatment of sole and multi cropping of groundnut with corn is significantly different for morpho-agronomic traits, including plant height, number of leaves and number of filled pods. The application of two rows of groundnut in between corn rows (T4) increases plant height significantly by almost double at 558 mm compared to the control at only 297 mm (Table 3). The trait of the number of leaves also shows a similar response to plant height, where groundnut leaves were significantly higher under multi cropping than sole cropping. However, the trait of the number of filled pods does not show a similar response to plant height and the number of leaves because the treatment of multi cropping between corn and groundnut at the ratio of 1:1 (T3) and the ratio of 1:2 (T4) significantly reduces the number of filled pods by 47% and 68%, respectively, relative to control (Table 3). In addition, the treatment of multiple cropping does not significantly differ between fresh crop biomass and stem circumference of groundnut (Table 3).

The yield of groundnut is significantly correlated with the number of pods, pod fresh weight and the number of leaves (Table 4). A positive correlation was identified between yield and the number of filled pods and fresh biomass at 0.95 and 0.70, respectively, while a negative correlation was identified between yield and the number of leaves at -0.72 (Table 4).

Plant height was significantly correlated with the number of leaves and stem circumference at 0.79 and 0.70 (Table 4). Fresh biomass was correlated with stem circumference at -0.74.

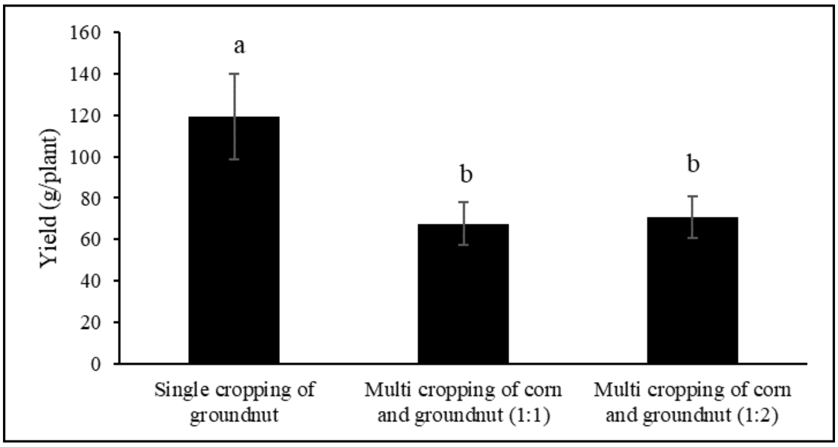

Figure 2. Yield of groundnut (fresh weight of unpeeled groundnut) under sole cropping and multi cropping with corn. The multi cropping was applied by growing groundnut in between corn rows. The application of groundnut was one row in between corn rows for application of 1:1 (T3) and two rows in between corn rows for application of 1:2 (T4). The yield of groundnut was the rate of fresh harvest of pods in the net plot 100 days after sowing

Table 3. Multiple comparisons (Tukey HSD) of groundnut cropping treatments of plant height (mm), number of leaves, stem circumferences (mm), number of pods and fresh biomass (g $plant^{-1}$) by one-way ANOVA

Treatment	Plant height (mm)	Number of leaves	Stem circumference (mm)	Number of filled pods	Fresh biomass (g)
Groundnut	297.8 ± 123.8^{b}	14.4 ± 0.1^{b}	5.3 ± 0.1	27.7 ± 5.7^{a}	178.7 ± 17.4
Corn Groundnut (1:1)	497.7 ± 68.2^{ab}	45.7 ± 2.6^{a}	7.7 ± 1.9	14.7 ± 2.7^{b}	106.6 ± 83.4
Corn Groundnut (1:2)	558.5 ± 21.5^{a}	58.6 ± 11.4^{a}	6.6 ± 0.5	8.8 ± 5.5^{b}	130.5 ± 13.7
F probability (*P*)	<0.05	<0.01	Ns	<0.05	Ns

Note: Differences between treatments were significant ($P < 0.05$) for all traits, except for crop fresh biomass and stem circumference.

The differences between treatments are shown as different letters (Tukey HSD, $P = 0.05$). Data are means followed by the error of three replicates. The traits of plant height (mm), number of leaves and stem circumferences (mm) were recorded one week before harvest, and number of pods and fresh biomass (g) were collected during harvest.

Ns= non-significant

Corn Groundnut (1:1) = one row of groundnut in between corn rows (T3)

Corn Groundnut (1:2) = two rows of groundnut in between corn rows (T4)

Table 4. Pearson correlation (r) between morpho-agronomic traits from corn cropping treatments – plant height (mm), number of leaves, stem circumferences (mm), number of pods, yield (g plant^{-1}) and fresh biomass (g plant^{-1})

	Plant height (mm)	Number of leaves	Stem circumference (mm)	Number of filled pods	Fresh biomass (g plant^{-1})
Number of leaves	0.79*				
Stem circumference (mm)	0.70*	0.73*			
Number of filled pods	-0.34	-0.71*	-0.54		
Fresh biomass (g plant^{-1})	-0.23	-0.56	-0.74*	0.66	
Yield (g plant^{-1})	-0.41	-0.72*	-0.5	0.95***	0.70*

Note: The traits of plant height, number of leaves and stem circumference were collected one week before harvest (reproductive stage of R6) from a total of groundnut net plots (n = 9). Number of filled pods, fresh biomass and yield were recorded at harvest.

*p < 0.05; **p < 0.01; ***p < 0.001

3.5. Land Equivalent Ratio of Corn and Groundnut

The application of multiple cropping between corn and groundnut is recommended because the value of the land equivalent ratio is more than 1.0 (Table 5). The value of land equivalent ratio between one row and two rows of groundnut treatments in between corn rows is insignificant (Table 5).

Table 5. Land equivalent ratio of four cropping treatments using the yield estimation by one-way ANOVA

Treatment	Corn yield (ton ha^{-1})	Groundnut yield (ton ha^{-1})	Land equivalent ratio
Corn	6.0	-	-
Groundnut	-	11.9^{a}	-
Corn Groundnut (1:1)	8.6	3.4^{b}	1.7
Corn Groundnut (1:2)	12.4	7.1^{ab}	2.7
F probability (*P*)	Ns	<0.01	Ns

Note: Values within a column followed by different letters indicate a significant difference with the Tukey HSD at p = 0.05. Differences between treatments were significant for yield of groundnut, and not significant for yield of corn and land use ratio. Land equivalent ratio was calculated from the comparison between yield of sole and multiple cropping system.

4. Discussion

The multiple cropping between crops and legumes has been commonly used in corn [11,12] sunflower (*Helianthus annuus* L.) [20] and potato (*Solanum tuberosum* L.) [21]. In this experiment, groundnut seeds were sown between corn rows, and the corn yield was not affected by the growth of groundnut in between corn rows (Figure 1). However, the yield of groundnut was significantly lower in multiple cropping than in sole cropping (Figure 2), probably because there was a competition in the environment, such as light and soil nutrients [11,14]. In corn, the yield is positively correlated with the number of leaves (Table 2) [22], but the yield of groundnut is negatively correlated with the number of leaves (Table 4). The land equivalent ratio was between 1.7 and 2.7, indicating that multiple cropping between corn and groundnut is more beneficial than sole cropping, similar to that shown in previous studies by Wibisana et al. (2017) and Rochmah et al. (2020).

The corn yield in sole cropping is often lower than in multiple cropping with legumes [11,12]. However, in this experiment, the corn yield in sole cropping was similar to corn in multiple cropping (Figure 1). This corn yield is similar between sole cropping and multiple cropping, probably because corn grown in sole cropping received similar light intensity to corn grown in multiple cropping due to their similar number of leaves (Table 1). This similar number of leaves among treatments can probably result in similar light intensity and concentration of chlorophyll for photosynthesis [23]. Varvel et al. (1997) added that a high chlorophyll concentration on the leaves positively correlates with a corn yield (kg ha^{-1}). This experiment also agrees with previous studies, where the number of leaves positively correlated with corn yield (Table 3,21,24].

Groundnut productivity is often lower in multiple cropping than in sole cropping [11, 12]. This study shows a similar response to the previous studies by Wibisana et al. (2017) and Rochmah et al. (2020), where the yield of groundnut in sole cropping is higher at 119.2 g plant^{-1} than in multiple cropping at less than 71 g plant^{-1} (Figure 2). The low yield of groundnut in multiple cropping is probably due to a low light intensity similar to that shown in multiple cropping between soybean and corn [25]. Liu et al. (2017) [25] added that the light intensity of legumes under intercropping with corn was 17-21% lower than that of legumes under sole cropping.

Growing legumes with corn in multiple cropping can increase legume plant height and the number of legume leaves [25, 26]. This study also agrees with previous studies by Gong et al. (2015) [26] and Liu et al. (2017) [25], where groundnut plant height and the number of groundnut leaves increased by more than 80% and 100%, respectively (Table 3). The rise in plant height can be caused by a response to low light intensity in groundnut, where groundnut grows taller to find an optimum light intensity (shade avoidance) similar to that shown in shade-tolerant soybean genotypes [26]. The increased number of legume leaves during intercropping can also be caused by a morphological response of groundnut to find optimum solar radiation for photosynthesis [27, 28].

The yield of legumes grown under multiple cropping is negatively correlated with the number of leaves and positively correlated with biomass [28]. The result in this study also shows a similar result to the previous study by Ginwal et al. (2019), where groundnut yield is significantly correlated with the number of leaves at -0.76 and with biomass at 0.70 (Table 4). The significant correlation is probably caused by a ratio of yield and biomass (shoot), where energy is used more to grow and develop shoots to find solar radiation for photosynthesis than to produce yield [29].

The value of land use equivalent to multiple cropping between corn and groundnut is between 1.5 and 3.0 (Table 5). This value means that the multiple cropping between corn and groundnut is more land-use efficient than sole cropping, similar to that shown in previous experiments by Wibisana et al. (2017) [11] and Rochmah et al. (2020) [12]. Table 5 also shows that the treatments of one and two groundnut rows grown between corn rows are not significantly different, which means that both treatments are suitable to be applied, similar to the previous study by Rochmah et al. (2020) [12]. However, the yield of groundnut in multiple cropping is significantly lower than in sole cropping (Figure 2; Table 5), probably due to low light intensity and competition of soil nutrients [14]. The competition for soil nutrients may occur due to the same sowing time and crop development, such as flowering time between corn and groundnut [11, 14].

5. Conclusions

There was no significant difference in corn yield between multiple cropping and sole cropping. However, the groundnut yield was significantly lower in multiple cropping at <71 g plant-1 than in sole cropping at 119 g plant-1. The groundnut grown under multiple cropping produces more leaves and taller plants than grown under sole cropping. The high number of leaves and tall groundnut crops could be caused by a response to low light intensity in groundnuts, where groundnuts grew taller and produced more leaves to find an optimum light intensity (shade avoidance). There was a positive impact on land use efficiency because the value of the land equivalent ratio in multiple cropping is more than 1.0, and the value of the land equivalent ratio was not significantly different between treatments of corn and groundnut at a ratio of 1:1 and a ratio of 1:2.

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Conflict of Interest

The authors declare there is no conflict of interest.

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