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RESEARCH ARTICLE
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Overcoming Competition from Intercropped Legumes on upland Rice (*Oryza sativa* L.) with Seeding Rates and Suitable Legume

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ABSTRACT

Upland rice (*Oryza sativa* L.) is a staple cereal in upland farming systems; however, its inherently low productivity often necessitates intercropping to enhance overall land use efficiency. Among intercropping strategies, integration with legumes has shown promise due to their nitrogen-fixing ability and contribution to system sustainability. Nevertheless, most existing studies have primarily emphasized total system productivity, with legume yield often disproportionately influencing outcomes. The present study aimed to improve the performance of upland rice by evaluating increased seeding rates and identifying the more suitable legume intercrop for optimizing both rice yield and system productivity. A two-factor experiment was conducted using a Randomized Complete Block Design (RCBD) with three replications. Factor A consisted of varying seeding rates of rice, while Factor B represented two intercropping systems: rice intercropped with mungbean (*Vigna radiata*, CS-M) and rice intercropped with cowpea (*Vigna unguiculata*, CS-C). The data collected for both rice and legumes included the leaf area index (LAI), the dry matter yield (DMY), and the land equivalent ratio (LER). For rice, it also included the harvest index (HI), the number of panicles, the number of filled grains per panicle, the weight of 1000 seeds, and the grain yield. For legumes, it also included the number of branches and pods per plant, the number of seeds per pod, the weight of 100 seeds, and the seed yield. The results showed that CS-C at a rate of 75kgha^{-1} (SR-2) gave the most rice grain production and Land Equivalent Ratio of 1.18. These results were attributed by higher 1000-seed weight and grain yield of rice, and high harvest index. In contrast, rice yields under the CS-M and CS-C systems were 60% and 38% lower, respectively, compared to sole rice cultivation, regardless of seeding rate. The reduced yield in the CS-M system was likely due to excessive shading caused by the dense branching of mungbean plants, which suppressed rice growth. Overall, the study suggests that intercropping upland rice with cowpea at a seeding rate of 75kgha^{-1} offers a more effective strategy to enhance rice productivity and land use efficiency. These findings highlight the importance of selecting appropriate legume species and optimizing planting density to improve the performance of upland rice-legume intercropping systems.

Keywords: Upland rice, Legumes, Cropping system, Seeding rate, and productivity

INTRODUCTION

Upland rice (*Oryza sativa* L.) is a critical component of upland agroecosystems in the Philippines and across Asia, where it contributes significantly to food security (Mamiit et al., 2020). In the Philippines alone, upland and lowland rice are cultivated on approximately 4.81 million hectares, yielding an estimated 19.96 million metric tons annually, underscoring its central role in the national agricultural economy (Lagasca et al., 2024). Grain legumes, on the other hand, offer substantial benefits by enhancing nutritional security through protein supply and improving the livelihoods of smallholder farmers via increased income (Akchaya et al., 2025). Their integration into rice-based systems through intercropping represents a synergistic strategy aimed at enhancing agricultural productivity, resource-use efficiency, and long-term sustainability. The Philippines faces significant challenges, with upland rice production, with an average yields of 1.7t/ha (Santosa et al., 2024). This yield shortfall is due to several factors, including

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the naturally low soil fertility (Suriyagoda, 2022), the fact that upland ecosystems are very dry, and the fact that traditional rice cultivars have a low harvest index. In addition, the widespread practice of cereal monocropping in these acid upland areas makes soil fertility even worse (Stamm et al., 2020). To close the gap between supply and demand for rice, we need to make rice production more technically efficient. This is important because of rising demand, depleted natural resources, climate change, and changing trade agreements (Arango-Londoño et al., 2020).

Intercropping upland rice with legumes is a great way to boost agricultural productivity and encourage environmentally friendly farming practices, especially in areas with limited land resources (Manasa, 2021). Kumawat (2022) says that planting rice and legumes together improves soil fertility and the use of resources. Intercropping can have benefits for biodiversity and resource use, but it can also have unexpected effects on the yield of main crops like rice. In an intercropping system, it is normal to expect that the yield of a single crop will be lower than that of a single crop. When two or more crops grow in the same area, they will always fight for things like sunlight, water, and nutrients. There will always be competition, even if the crops grow in ways that help each other or need different nutrients. The intercrop (like a legume) may stress the main crop (like rice), which could lower its yield compared to if it were grown alone with all its resources (Moreira et al., 2024). Mugisa et al. (2020) data show that when rice is grown with corn, beans, and groundnuts, the yield drops by 35% to 48%. Intercropping rice with beans, groundnuts, and soybeans causes a loss of 19.80% of the rice yield, according to Kaiira et al. (2024). Even though overall LERs were usually greater than one, showing a total yield advantage, competition lowered the yield of each individual rice plant. Old literature also mentions a big drop in yield as something to think about.

Efforts have been made to improve rice performance under an intercropping system, like spatial arrangement of intercrop components, which deals with the row ratio between rice and legumes (Papong et al., 2020). Paired Rows or Skip Row Planting involves planting rice in "paired" rows (two rows close together) followed by a wider inter-row space where the legume is planted by Kaiira, et al. (2024) and Temporal Intercropping by Cagasan et al. (2023). All these were done to overcome substantial loss of rice intercropped with legumes. However, no study has been done to find the optimum rice seeding rate when intercropped with legumes. Furthermore, the success of intercropping rice depends on choosing a companion crop that complements rice in terms of growth habits, resource needs, and maturity period (Huss et al., 2022). Rather than simply growing multiple crops in the same space, selecting species that exhibit beneficial interactions with the primary crops in the intercropping system is important. Hence, the study aimed to find the optimum seeding rate for rice intercropped with legumes and choose a more suitable legume intercrop.

MATERIALS & METHODS

The rice variety chosen for the experiment, PSBRi-1, commonly known as Makiling, with an average yield of 3,272kgha^{-1} and moderate resistance to rice blast. It performs well on acidic upland soil and is moderately resistant to drought at the vegetative stage. It reached a height of 104cm and matured 121 days after emergence. PSB-Mg-2, commonly known as Mabunga, is a mung bean variety. It had a potential yield of 1,304kgha^{-1} during the wet season. It is moderately resistant to cercospora leaf spot, rust, and viruses. It matures 60–62 days after planting and can reach 78–85cm. The cowpea variety EG22 (BPII-Cp3), Masipag 1, was used. It is moderately resistant to pod borer and highly resistant to rust, fusarium wilt, and mosaic virus. It has a potential yield of 1,470kgha^{-1} during the wet season. The selection of legumes, such as cowpeas and mung beans, was influenced by their use in vegetables, desserts, and refreshing drinks like halo-halo, which are popular in the warm climate of the Philippines.

The experiment was a two-factor factorial arranged in a randomized complete block design and replicated three times (Table 1). Factor A included the seeding rate SR; SR-1 (125% of the recommended seeding rate or 94kgha^{-1}), SR-2 (100% of the recommended seeding rate or 75kgha^{-1}), and SR-3 (75% of the recommended seeding rate or 56kgha^{-1}) for intercropping, whereas for sole crop rice, the SR-1, S-2 and SR-3 are 125kgha^{-1}, 100kgha^{-1}, and 75kgha^{-1}, respectively. Factor B comprised various cropping systems (CS), which included CS-C (rice + cowpea), CS-M (rice + mungbean) and CS-R (sole rice). The sole mung bean and cowpea served as control treatments for the legume component. The recommended seeding rate for upland rice was 100 kg ha-1 and that for legumes was 40kgha^{-1}. The seeding rates were adjusted in proportion to the plot size in the experimental field.

Table 1: Tabular representation of the two-factor factorial, where Factor A represents the Intercropping system, while Factor B represents the seeding rate

Factor A (Intercropping System)	Factor B (Seeding Rate kgha^{-1})
CS-C (Rice + Cowpea)	SR-1 (94)
	SR-2 (75)
	SR-3 (56)
CS-M (Rice + Cowpea)	SR-1 (94)
	SR-2 (75)
	SR-3 (56)
CS-R (Rice)	SR-1 (125)
	SR-2 (100)
	SR-3 (75)
CS-C (Cowpea)	
CS-M (Mungbean)	

A total experimental area of 4,000m^2 was plowed once and harrowed twice with tractor-drawn implements. After the second harrowing, furrows were laid 30cm apart across the field. The field was divided into 3 blocks with each block consisting of 6 plots each block, having an area of 25m^{-2} each. Each plot has furrows 30cm apart. Drill method of planting was used during planting. For intercropping, the arrangement was 4:2 raw ration, 4 rows of rice alternately planted with two rows of mungbean or cowpea. The distance between forrows for rice was 30cm apart while for legumes were 60cm apart (Fig. 1). An area of 7.2m^2 at the center of the plot was used for yield determination in both rice and legumes.

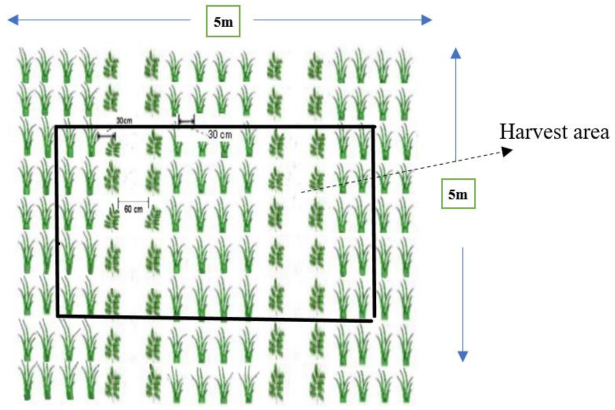

Fig. 1: Intercropping pattern of rice and legumes at 4:2 a row ratio with marked harvest area.

For monocrop rice and legumes, seeds were drilled in their respective rows in each plot, while for intercropped rice, rice seeds were drilled in their respective rows ahead of legumes. After 30 days from seedling emergence of rice, the legumes seeds were drilled on their respective row. Thinning of legumes seedling were done a week after seedling emergence and maintained 8 seedling per linear meter. The crops were fertilized based on the recommended fertilizer for rice and legumes. The amount of fertilizer was calculated based on the area occupied by rice or legumes. The field was irrigated once a week except on rainy days. Both legumes flower almost the same time, and the pods are allowed to ripen in the plant before it is harvested. Harvesting of the pod was done at 5-day intervals. The yellow to brown pods were harvested and dried for two days before they were threshed to extract the seeds. Using a moisture meter, the yield of both legumes was adjusted to 12% MC during yield calculation.

In both sole and intercropped upland rice were harvested when 85% of the grains in the panicle turned yellow. The rice was threshed immediately after harvesting, and the grain or "palay" was dried for two days. Using a moisture meter, the weight of rice was adjusted to 14% MC using Formula C.

Agronomic measurements for rice include leaf area index (LAI) using a semi-automatic leaf area meter (Li 3000), dry matter yield (DMY) at 80 days after emergence (DAE), land equivalent ratio (LER), harvest index (HI), number of panicles, number of filled grains per panicle, weight of 1000 grains, and grain yield. LAI was measured using a semi-automatic leaf area meter (Li 3000), DMY at 80 (DAE), number of branches per plant, number of pods per plant, number of seeds per pod, weight of 100 seeds, and seed yield.

Formula A. Leaf areas index (LAI) was calculated as (Hashimoto et al. 2023)

$$LAI = \frac{\text{Leaf Area}}{\text{Ground Area}}$$

Where: Leaf Area is generated from the lea portable Leaf Area Meter (Li-3000)

Ground Area - the distance between hills and farrow

Formula B. Land equivalent ratio (LER) was calculated as defined as (Namozov et al., 2021)

$$LER = \frac{Xi}{Xm} + \frac{Yi}{Ym}$$

Where: Xi and Y =yield of intercropped component

Formula C. Seed yield was calculated as

$$\text{Seed yield (t ha}^{-1}\text{)} = \frac{A_1}{A_2} \times Yi \times \frac{100\text{-MC}}{100 - \text{SMC}}$$

Where: A_1 = area per hectare 10,000 m^2 ha^{-1}

A_2 = area per plot ($7.2m^2$)

Yi =seed yield ($kgplot^{-1}$)

MC = Moisture content (14% for rice & 12% legumes)

SMC = Seed moisture content

Xm and Ym =yield of monocrop

Formula D. Dry matter yield (DMY) was calculated as

$$DMY = \frac{W}{G_A}$$

Where: **W** - dry weight of either rice and legumes

G_A - ground area occupied by the sample

Formula E. Harvest index (HI) by Zhang et al. (2022)

$$HI = \frac{\text{Economic Yield (Dry Weight)}}{\text{Total Above-Ground Biomass (Dry Weight)}}$$

The effects of each treatment were tested using variance analysis (ANOVA). If the results indicated a significant difference, a further mean comparison was conducted using either the Least Significant Test (LSD) or Duncan's Multiple Range Test (DMRT), ensuring the validity of the conclusions.

RESULTS

Edaphic and Abiotic Characteristics of the Experimental Area

The study was conducted at the Central Experimental Station, College of Agriculture, University of the Philippines, Los Banos, Laguna, Philippines (Fig. 2). The soil in the area has a pH of 5.7, 1.5% organic matter, and the available P is 25.5ppm and 1.11 (meq/100g soil). Nitrogen in the field was very low (0.12%), and the soil texture was clay loam with a 26.40meq/100g soil. During the study, the daily mean rainfall was 14.87mm, and the average solar radiation was 21.04 to 20.10$MJm^{-2}min^{-1}$ daily.

Lear Area and Dry Matter Yield of Upland Rice and Legumes

Table 2 presents sole and intercropped upland rice leaf area index (LAI) and dry matter yield (DMY) at 80DAE. The LAI of CS-C and CS-M at SR1 and SR2 were statistically similar and statistically higher than CS-C and CS-M at SR3. The LAI of CS-R was statistically lower than rice intercropped with legumes. In general, the LAI increases with increasing seeding rate. The DMY of intercropped upland rice, particularly the CS-C and CS-M at SR1 and SR2 were statistically similar, and significantly higher than the SR3 of both CS. Sole rice (CS-R) had the lowest DMY compared to intercropped rice. The maximum DRY and LAI of sole and intercropped legumes at 60 DAE were also presented in Table 2. The LAI of CS-C and CS-M at SR1 and SR2 were statistically similar. However, between the two-cropping systems, CS-M at SR1 and SR2 were 8 percent higher than CS-C at the same seeding rate (SR). Statistical analysis shows that the rice seeding rate does not significantly affect the DMY of legumes. But in terms of quantity, the DMY of rice intercropped with mung bean (CS-B) was at SR1, SR2, and SR3, which were 12.60, 8.64, and 12.6% percent higher than CS-C at the same seeding rates respectively.

Table 2: Leaf area index and dry matter yield of monocrop and intercropped upland rice and legumes affected by different seeding rates and cropping systems

TREATMENT	Upland Rice (80 DAE)		Legumes (60 DAE)	
CS / SR	LAI	DMY (g m^{-2})	LAI	DMY (g m^{-2})
CS-C				
SR-1 (94 kg ha^{-1})	5.13a	372.75a	3.73b	454.97
SR-2 (75 kg ha^{-1})	4.71ab	398.83a	3.86b	474.85
SR-3 (56 kg ha^{-1})	3.89d	336.40b	3.88b	456.37
Cowpea	-	-	4.21ab	463.12
CS-M				
SR-1 (94 kg ha^{-1})	4.85ab	389.76a	4.03ab	512.37
SR-2 (75 kg ha^{-1})	4.79ab	394.11a	4.17ab	515.88
SR-3 (56 kg ha^{-1})	3.45e	307.55c	4.55a	510.22
Mungbean	-	-	4.52a	500.36
CS-R				
SR-1 (125 kg ha^{-1})	4.10c	280.51d	-	-
SR-2 (100 kg ha^{-1})	4.18c	296.59c	-	-
SR-3 (75 kg ha^{-1})	3.41e	289.73cd	-	-
C.V.	10.49	10.60	12.14	9.5

DAE (Days After Emergence); Means in each column with the same letter are not significantly different at 5% level (DMRT)

Harvest Index (HI) of Upland Rice

The HI of rice at different seeding rates does not significantly affect the CS, as shown in Table 3. Among the CS, rice intercropped with cowpea obtained significantly higher HI of 0,35. This is 26 and 14.29% higher in CS-M and CS-R respectively. It indicates that large portion of assimilates is used in the development of economic yield. This could be the reasons why rice panicle and seed weight are much heavier in CS-C compared to the rest of cropping system. On the other hand, the partition of assimilate is much higher on grain development in CS-C than in the other cropping system. This condition only happens when rice get enough sunlight. This condition only happens when rice gets enough sunlight.

Number of Panicles of Upland Rice

The number of panicles increased with increasing seeding rate, regardless of cropping system (Table 3). Intercropped rice at SR-1 had 8.70% more panicles per square meter than SR2. The low number of panicles per square meter in SR-3 was due to low plant density. There were no significant differences in the number of panicles across the CS, indicating that neither mung bean nor cowpea intercropping affected the number of rice panicles per square meter. Furthermore, the interaction effect was insignificant, which means that the combined effect of different CS and SR did not influence the number of panicles.

Number of Filled Grains in a Panicle

The interaction between CS and SR did not significantly affect the number of filled grains in the panicle. However, different SRs significantly affected the number of filled grain. Table 3 shows that SR-1 was 28.14% less filled grain per panicle than SR-2. However, the SR-2 was also 4.26 lower than that of SR-3. It appears that the plant population significantly affects the number of filled grains.

Weight of 1000 Seeds of Upland Rice

Both SR and CS showed significant changes in the weight of 1000 grains (Table 3), but the interaction between SR and CS was negative. Regarding CS, rice intercropped with cowpea obtained significantly higher 1000-grain weight. This was followed by CS-M with a mean of 22.54. Sole rice (CS-R) was 2.01 grams lower than CS-C. The grain weight of 1000-seed decreased with increasing rice SR. The results showed an opposite trend between the number of panicles and filled grains**.** As the number of panicles increased, the 1000 seed weight decreased. Hence, SR1 is 2.5 percent lower than SR-3.

Grain Yield of Upland Rice

The grain yield of sole rice (CS-R) was significantly higher than that of intercropped rice (Table 3). Among the intercropped rice, rice intercropped with cowpea (CS-C) was considerably higher than CS-M. Comparing the yield of two cropping system to sole rice, CS-C and CS-M were 39 and 60 percent lower than sole rice (CS-R) respectively. Hence, the rice yield reduction due to intercropping was 38 and 60 percent for CS-C and CS-M respectively compare the sole rice. Regarding the rice seeding rate, SR-2 obtained the highest grain yield across cropping system. Increasing the seeding rate from SR2 to SR1 resulted in an 18% lose in grain yield while reducing the SR from SR-2 to SR-3 reduces the yield by 23%.

Table 3: Harvest index, panicle count (m^2), number of filled grains per panicle, weight of 1000-seed, and grain yield of monocrop and intercropped upland rice are affected by different seeding rates and cropping systems

Treatments	Harvest index	No. of panicle (m^2)	No. filled grain per panicle	Weight 1000-seed (g)	Grain yield (kg ha^{-1})
Cropping System					
CS-C	0.35a	289	119	23.52a	1902.47b
CS-M	0.26c	270	130	22.54b	1222.69c
CS-R	0.30b	280	129	21.51c	3068.36a
LSD (0.05%)	*0.036*	*ns*	*ns*	*0.232*	*210.25*
Seeding Rate[1] (Kgha^{-1})					
SR-1 (94kgha^{-1})	0.30	321a	97c	22.25c	1965.90b
SR-2 (75kgha^{-1})	0.29	293b	135b	22.58b	2385.80a
SR-3 (56kgha^{-1})	0.32	223c	141a	22.82a	1841.82c
LSD (0.05%)	*ns*	*42.36*	*16.09*	*0.232*	*210.25*
Coefficient of variation	*12.39*	*10.05*	*12.97*	*1.03*	10.19

[1].Seeding rates of monocrop rice were 125, 100, and 75 kg ha^{-1}

Table 4: Yield components of monocrop and intercropped legumes affected by different rice seeding rates

TREATMENT Rice Seeding Rate (kg ha^{-1})	No. of branches (m^3)	No. of pods per plant	No. of seeds per pod	Weight of 100-seeds (g)	Seed Yield Kg ha^{-1})	LER
CS-C						
SR-1 (94)	249b	12c	13.33a	11.02a	426.62d	1.21a
SR-2 (75)	253b	14c	12.33ab	11.06a	483.66d	1.18a
SR-3 (56)	218b	15c	12.33ab	11.14a	440.37d	1.22a
Sole Cowpea	200b	16c	13.33a	11.81a	783.52c	1.00b
CS-M						
SR-1 (94)	347a	47ab	12.00bc	5.527b	762.41c	0.91bc
SR-2 (75)	378a	36b	11.66bc	5.77b	754.95c	0.86c
SR-3 (56)	378a	48ab	1133bc	5.73b	1032.08b	1.00b
Sole Mungbean	369.a	58a	11.00c	5.44b	1508.98a	1.00b
LSD $_{(0.05)}$	61.38	15.43	1.32	1.52	134.37	0.15
C.V.	11.72	28.69	6.18	10.25	9.91	6.26

Means in each column with the same letter are not significantly different at 5% level of significance.

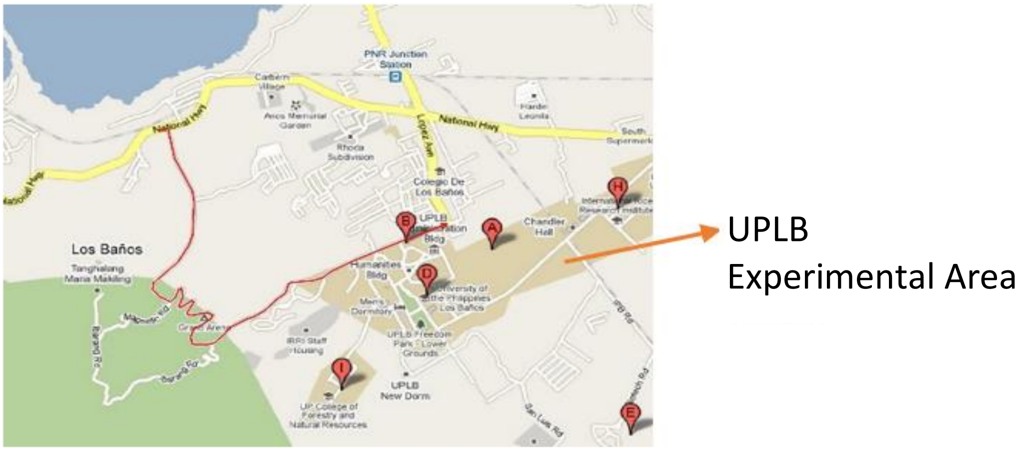

Fig. 2: Location of the study.

Number of Branches, Number of Pods per Plant, Number of Seeds per Pod, and Weight of 100 Seed, Seed Yield, of Legumes Intercrop and LER

Table 4 shows that the number of branches and pod per plant in CS-M is significantly higher than CS-C regardless of seeding rates. However, the number of seeds per pod in CS-C was numerically higher than CS-M. In terms of weight of 100-seed, the seeds of CS-C were significantly heavier regardless of seed rate. Considerably, the sole mungbean or cowpea seed yields were much higher than their respective intercrop. The yield of CS-M was significantly high in SRI, then gradually reduced at SR2 and SR3, while the yield of CS-C was significantly low compared to the CS-M regardless of seeding rate. The LER on Table 4 shows that CS-C were significantly high regardless of seeding rate. The LER of CS-C was 21% in SR1, 18% in SR2, and 22% in SR3, higher than that of sole crop cowpea. This indicates that the productivity of the cropping system depends on the legumes intercropped with rice.

DISCUSSION

Response of Different Seeding Rate of Upland Rice Intercropped with Legumes

Selecting an appropriate seeding rate is crucial for optimizing yield and resource utilization in upland rice intercropping systems, requiring careful consideration of various factors, including cultivar characteristics, environmental conditions, and intercrop compatibility (Li et al., 2020a). Furthermore, finding suitable legumes presents a promising strategy to mitigate these constraints and enhance the productivity and sustainability of upland rice systems (Hairmansis et al., 2021). The grain yield of upland rice was significantly high at optimum seeding rate (SR2; Table 3). The optimum seeding rate for intercropped rice was 75kgha^{-1} which is equivalent to 100kgha^{-1} if planted as sole crop at 30cm row spacing, yielded 3.068 t ha^{-1}. This research output was similar to the work of Jenber et al. (2020), on monocrop upland rice, wherein the optimum seeding rate of 100kgha^{-1} obtained 3.46t/ha at 15cm instead of 30 cm row spacing. The results of the study suggesting a nuanced relationship between plant density and resource utilization (Li et al., 2020b). On the other hand, at low seeding rate (SR3), individual rice plants experience reduced intraspecific competition, allowing them to access a greater share of available resources such as light, water, and nutrients (Manasa, 2021). This is why the number of filled grain and weight of 1000-seed was significantly high at SR3 (Table 3). The low yield of SR3 was mainly attributed to a low number of panicles. Rao et al. (2020) state that higher seeding rates, which lead to a greater overall plant density, can exacerbate competition among rice plants, limiting individual plant growth and yield potential. The result also shows that the seeding rate (SR1) obtained the lowest number of filled grain and weight of 1000 seeds. The result also shows that the seeding rate (SR1) obtained the lowest number of filled grains and a weight of 1000 seeds. Li et al. (2020a) explained that the diminished yield observed with high seeding rates is intricately linked to a consequential reduction in the number of panicles per plant, a critical determinant of overall grain production. Furthermore, the results in this experiment indicate an inverse relationship between seeding rate and grain quality, as evidenced by the reduced number of filled grains and diminished 1000-seed weight observed under high seeding rate conditions. Manasa (2021) concluded that high productivity in upland rice intercropped with legumes when employing a minimum seeding rate can be attributed to the superior yield of the upland rice component under these conditions.

The Effect of Legumes on Rice Intercrop

Rice intercropped with cowpea (CS-C) at optimum seeding rate of 75kgha^{-1} shown in Table 3, obtained higher yield compared to rice intercropped with mungbean. Papong et al. (2020) reported that rice intercropped with peanut, using optimum rice seeding rate of 60kgha^{-1} (drilled in furrow), resulted in the highest rice grain yield of 2.8t/ha and the highest gross margin compared to upland rice intercropped with mungbean. The high grain yield of SC-C was attributed to high HI and 1000-seed weight. According the Zhang et al. (2022) that harvest index (HI) is the ratio of harvested seed weight to total aboveground biomass weight. The more carbohydrate from photosynthesis that translocate to grain, the higher the HI. Feng et al. (2024) investigate the impact of photosynthetic active radiation (PAR) on rice grain filling and stated that increased sunlight exposure during grain filling stages enhanced grain weight significantly by improving carbohydrate translocation. Li et al. (2020b) showed that rice plants grown under shaded conditions had reduced grain weight compared to those under full sunlight, indicating the importance of sufficient sunlight for heavier grains. Hence, CS-C received enough sunlight and has more efficient partitioning of resources towards grain production, leading to higher yields (Cantila & Quitel, 2020). Table 3 also showed that rice yield reduction due to intercropping was 38% in CS-C, while in CS-M was 60%. The high reduction of yield in rice intercropped mungbean was attributed to a high number of mungbean branches compared the cowpea (Table 4). Khan et al. (2020) reported that mungbean exhibited higher competitive ability when intercropped with cotton resulting to adversely effect to the number of opened, total bolls plant^{-1}, opened boll percentage and seed cotton yield in all intercropping systems. Abraheem et al. (2024) also reported that mungbean intercropped with sorghums exhibited high Aggressivity value, making it more aggressive than sorghum. According to Stamm and Kumar (2020), when mungbeans are shaded by a denser rice canopy, they may respond by increasing branching to increase the light capture surface area and access more sunlight for photosynthesis because mungbean has a shade avoidance response mechanism regulated by plant hormones, such as auxin and cytokinin, which balances these hormone shifts, promoting stem elongation and branching to try and outgrow the shade. Zustovi et al. (2024) summarized that mungbeans aggressive canopy development reduces light availability to companion crops more than cowpea. Furthermore, Labrador et al. (2024) found that intercropping rice with mungbean has no significant effects on nitrogen-related growth parameters (e.g., LAI, CGR, and RGR) due to mungbean sowing time.

Cowpea on the other hand, was found to have less aggressive growth allowed better yield stability in intercropping systems (Victor et al. 2023). The complementary growth of rice and cowpea enhances overall productivity that contributes to the stability and resilience of the agricultural system, providing a buffer against environmental stresses and economic uncertainties (Nursalam et al., 2021). Cowpea intercropped with maize, exhibited higher average leaf nitrogen (N) concentration attributed to its leguminous nature with access to atmospheric N, benefiting the growth of maize in intercropping and cabbage cultivated as a succeeding crop (Dimande et al., 2024). Finally, Wang et al. (2023) reported that the strategic integration of legumes with upland rice exemplifies this approach, offering a pathway to optimize resource utilization and foster synergistic interactions within the cropping system.

Impact of Rice on Intercropped Legumes and LER

The DMY and LAI of CS-M (Table 1) are relatively higher than CS-C across seeding rate, indicating that mungbeans are bigger and have more leaves than cowpea. Neither the LAI and DMY of sole and intercropped cowpea and mungbean significantly affected by rice seeding rate. Similar result was reported by Meirelles et al. (2024) that *Crotalaria breviflora*, when intercropped with rice, maintained or even improved total dry mass production without significantly affecting rice grain yield. Under intercropping system, rice and legumes occupies 66.5 and 33.5% of the total area respectively. In relation to monocrop legumes (Table 4), the yield reduction of cowpea intercropped with rice was 45, 38, and 44% reduction in SR1, SR2, and SR3, respectively, while the yield reduction of mungbean due to intercropped rice was 49, 50, and 31 percent reduction in SR-1, SR-2, and SR3, respectively. By proportion, it appears that intercropped legumes exceeded the sole crop yield. For instant, the 38% yield of intercropped legumes is much higher than the 38% of sole legume. Mungbean with rice also has a higher number of branches and pods per plant than cowpea, regardless of seeding rate. The high number of branches in mungbeans causes intense shading on it rice counterparts. On the other hand, cowpea has a high number of seeds per pod and 100-seed weight.

The land equivalent ratio (LER) is a crucial metric for evaluating the efficiency of intercropping systems compared to sole cropping (Astiko et al., 2021). An LER value greater than one signifies that the intercropping system demonstrates enhanced land-use efficiency relative to the sole cropping of its constituent species (Namozov et al., 2021). The LER in Table 4, shows that the LER of CS-C is significantly high irrespective of seeding rate. The consistently high LER values for CS-C, ranging from 18% to 22% greater than sole crop cowpea across the different seeding rates (SR1, SR2 and SR3), strongly suggest a synergistic effect between the two species, leading to enhanced productivity. Similar findings were reported by Frimpong-Manso et al. (2022), who observed an LER of 1.26 in a rice–cowpea intercropping system under combined organic and inorganic fertilization. The consistently high LER values in the current study affirm the potential of cowpea as a compatible intercrop for upland rice to maximize land productivity.

Conclusion

According to the results, choosing the right intercrop and seeding rate are crucial for maximizing upland rice production in intercropping systems. In order to maximize grain yield, a optimum seeding rate for rice (SR2) strikes a balance between plant productivity and total stand density. Additionally, the study shows that cowpea and upland rice intercropping provides a more beneficial and fruitful system than mungbean intercropping. The consistently higher land equivalent ratio at different seeding rates indicates that cowpeas work better with rice because they grow less aggressively than mungbean. This results in higher rice yields and better use of land. Thus, there is a great deal of potential for increasing agricultural productivity and encouraging sustainable cropping methods in the area by incorporating cowpea as an intercrop with upland rice and using a suitable seeding rate. Intercropping rice yields, however, can have a wide range of effects. The types of rice and legumes used, planting density and arrangement, management techniques, and environmental circumstances are some of the causes of this. Crucially, some research has also discovered that intercropping improves soil health and rice yield, among other aspects of rice development.

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Conflict of Interest: The study here is the author's original idea and is not a duplication of any research. The authors declare no conflicts of interest.

Data Availability: My data is on this link: https://drive.google.com/drive/folders/1k7iyrw1ogpMXrkNsxXM6SVc2kHNO23o7?usp=drive_link

Ethics Statement: This study did not involve human or animal subjects; therefore, no institutional review board approval was required. However, I have taken all necessary precautions to ensure the ethical conduct of this research.

Author's Contribution: This study was the sole effort of the authors. The author is solely responsible for all aspects of the study, including conceptualization, methodology, data collection, analysis, writing, and manuscript preparation.

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