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RESEARCH ARTICLE
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Performance of Upland Rice Intercropped Legumes and Level of Nitrogen Fertilizer

Elmer Galo

Faculty/Researcher, Western Mindanao State University, College of Agriculture, Philippines
*Corresponding author: elmergalo74@gmail.com ; elmer.galo@wmsu.edu.ph

ABSTRACT

Upland rice, a key food source for farmers, is often studied to improve food production. This study aims to determine the optimal level of nitrogen required for upland rice under intercropping system and to determine suitable legumes that complement for the growth and yield of upland rice base intercropping. The experiment involved two factors where factor A consists of levels of nitrogen, and factor B consists of a cropping system. Measurements included leaf area index, dry matter yield, land equivalent ratio for rice and legume. For rice, the number of panicles, field grains per panicle, 1000-seeds weight, and yield; and for legumes intercropped is the number of branches and pod per plant, seeds per pod, 100-seeds weight, and seed yield. The best results were achieved when rice was grown with cowpeas and fertilized with 60kg of nitrogen per hectare, producing a rice yield of 1,492kg per hectare. Cowpea intercropping also showed a 26% increase in land equivalent ration (LER of 1.26) compared to growing rice alone. These were attributed to a high number of filled grains per panicle and 1000 seed weight. Growing rice with mungbeans resulted in a higher mungbean yield over cowpea of 819.54kgha^{-1}. However, the aggressive growth of mungbean by having more parallel branches and high LAI caused intense shading to its rice counterpart, which resulting in lower rice yield of 878.70kgha^{-1} and lower LER of 0.99. Therefore, the most suitable legume for intercropping rice is cowpea because it complements upland rice growth.

Keywords: Intercropping, Sole crop, Levels of nitrogen, Cropping system, LER.

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INTRODUCTION

Upland rice (*Oryza sativa* L.) is an essential source of food and nutrition for millions, particularly in hilly and mountainous regions (Khotasena et al., 2022). It provides food security, which contributes significantly to the daily diet and the economy. The cultivation of upland rice in the Philippines is deep rooted in indigenous communities as part of their culture and tradition (Zapico et al., 2020), adding to their culinary and cultural value. Farmers give more priority to rice over any other crops because the production of staple food is their primary concern. According to Zapico et al. (2020), prioritizing of rice over other crops underscores its importance as a staple food. The decision to focus on rice production stems from its essential role in meeting their families' dietary needs and securing a reliable food source. Furthermore, upland rice farming often incorporates sustainable practices, such as intercropping and agroforestry, which help maintain soil fertility and protect ecosystems (Maitra et al., 2021). These practices contribute to environmental conservation while ensuring the long-term viability of upland rice cultivation.

Intercropping is a sustainable farming practice involving growing two or more crops in the same field (Maitra et al., 2021). Most studies demonstrate clear benefits of intercropping for weed, pathogen, insect pest control, relative yield and gross profitability (Huss et al., 2022). Legumes improve soil health by increasing organic matter and nutrient content (Meirelles et al., 2024). This leads to better water retention, soil structure and overall fertility, reducing the need for costly soil amendments in the long run (Kebede, 2021). Intercropping can lead to higher productivity per unit area compared to monoculture (growing only one crop) by utilizing resources more efficiently (Huss et al., 2022). It also helps farmers mitigate risks associated with climate change, market fluctuations, and crop failures by diversifying their production (Shaffril et al., 2024; Mihrete et al., 2025). This can be particularly beneficial if one crop fails or market prices fluctuate.

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Intercropping legumes with rice has plenty of benefits, but this study highlights a potential drawback: if the legume grows too aggressively, it can outcompete the rice for sunlight, hindering its growth and reducing its yield. A study by Meirelles et al. (2024) reported that intercropping rice with legumes such as *Crotalaria spectabilis*, jack bean, and dwarf pigeon pea) significantly decreases rice grain yield compared to other legumes. Wangiyana et al. (2023) also reported that intercropping of upland rice with mungbean reduces the number of filled grains per panicle, eventually affecting the rice yield. The fast growth of legumes and dense canopy caused significant shading, hindering rice plant development and reducing yield. Hence, choosing compatible legumes is extremely important in such a way that compatible legumes and upland rice can complement each other's growth habits, leading to more efficient utilization of resources like sunlight, water, and nutrients (Rahajaharilaza et al., 2023).

Usually, upland rice is grown organically, with fewer cultural practices or management interventions such as the application of no fertilizer or too little fertilizers (Shah et al., 2021). These practices resulted in its lower yield, thus, treated only as a subsistence crop. Commonly, the crop is planted in marginal upland areas with highly degraded, infertile, and acidic soils (Wang et al., 2023; Santosa et al., 2024). It has been reported that the depletion of soil fertility in acid upland rice areas is further aggravated by continues cereal monocropping without nutrient application (Suriyagoda, 2022; Langangmeilu et al., 2023).

Nitrogen is the most deficient nutrient in the upland area (Hussain et al., 2022). Nitrogen in upland conditions is mostly in the form of nitrate (NO_3^-). And nitrate is a highly mobile form of nitrogen, making it susceptible to losses. Most of upland areas often experience higher rainfall, which can lead to significant leaching or nitrate (NO_3^-) erosion from the soil (Simelane et al., 2024). Furthermore, upland soils can have lower organic matter content compared to lowland soils. Organic matter is a crucial reservoir of nitrogen. Reduced organic matter means less nitrogen is available for plant uptake (Cao et al., 2021).

Nitrogen fertilizer plays a vital role in upland rice because it enhances plant growth, increase numb er of productive tiller and grain per panicle, expand leaf area, improves grain yield and boosts overall crop quality. Nitrogen is a key component of chlorophyll, amino acids, and proteins, essential for photosynthesis and plant development. Proper nitrogen management ensures better tillering, leaf area expansion, and grain filling, leading to higher protein content and overall productivity (Zhang et al., 2020; Berhane et al., 2020; Wang et al., 2023). Additionally, it helps maintain soil fertility and supports sustainable agricultural practices

Many studies have shown that rice yield increases with the increase of nitrogen application within a specific range, but the yield and nitrogen utilization rates also decrease when the nitrogen application is too high. Previous research shows that the nitrogen requirement of upland rice is less compared to lowland rice. Upland rice attained its maximum yield of 210kg N per hectare, while lowland rice attained maximum yield at 280kg per hectare (Zhang et al., 2020). The later result was probably using high levels of nitrogen. Hussain et al. (2022) reports that the maximum yield of upland rice was attained at 90kg N ha^{-1}. The yield was due to the high number of tillers, panicle and filled grains. The yield of 1,961 kg ha^{-1} was attained by upland rice intercropped with cowpea when applied with 45kg N ha^{-1} (Oroka, 2018). The incremental level used in this study was based on soil analysis and recommended fertilizer.

It is common knowledge that legumes can fix nitrogen through nitrogen-fixing bacteria called *Rhizobia*, which reside inside the nodules of the legume plant (Wang et al., 2019). However, in hybrid legumes, the demand for nitrogen fertilizer may exceed the amount they can biologically fix due to their rapid growth and high-yielding characteristics (Jimenez-Lopez et al., 2020). Consequently, it remains uncertain whether intercropped legumes can provide sufficient nitrogen to benefit upland rice when grown together. Few studies have been done about the levels of nitrogen for upland rice intercropped with legumes. Hence, the study aims to determine the necessary level of nitrogen specifically for upland rice under intercropping system and to determine suitable legume that complement the growth and yield of upland rice. Despite the potential advantages of intercropping, limited research has been conducted on the optimal nitrogen levels for upland rice cultivated alongside legumes. Therefore, this study aims to determine the specific nitrogen requirements for upland rice under an intercropping system and to identify the most suitable legume species that enhance its growth and yield.

MATERIALS & METHODS

The rice variety chosen for the experiment, PSBRi-1, commonly known as Makiling, holds promise with its average yield of 3,272kg ha-1 and moderate resistance to rice blast. It thrives on acid upland soil and shows resilience to drought at the vegetative stage, reaching a height of 104cm and maturing in 121 days from emergence. Meanwhile, PSB-Mg-2, commonly known as Mabunga, was a mungbean variety used. It has a potential yield of 1,304kgha-1 during the wet season. It matures 60 to 65 days from planting and may attain a 78 to 85cm height. The cowpea variety used was EG22(BPI-Cp3), commonly known as Masipag 1. It has a potential yield of 1,470kg ha-1 during the wet season. It matures (first harvest) 45 days from sowing. An area of 4,000m2 was plowed and harrowed to make the land suitable for planting. The area was subdivided into three blocks; each block contained 12 plots with a size of 5 x 5 meters. Furrows were established at 30 centimeters apart. The recommended seeding rates for upland rice and legumes were 100kg ha-1 and 40kg ha-1 if planted as the sole crop.

The study employed a two-factor factorial dinged. The treatments in study were arranged in a randomized complete block design with three replicates (Table 1). Factor A was the cropping systems, and factor B consisted of different levels of nitrogen fertilizer. The seeding rate for rice was 100kgha^{-1} rice while for mungbean and cowpea was, 40kg per hectare.

Table 1: Tabular representation of the treatment arranged in two factor factorial, where Factor A was the cropping systems and Factor B consist of different levels of nitrogen fertilizer

Factor A: Cropping Systems (CS)	*Factor B: Levels of Nitrogen (LN - kg ha^{-1})*
CS 1: Rice + mungbean	LN_1= 60
	LN_2= 40
	LN_3= 20
	LN_4= 0
C_2 Rice + cowpea	LN_1 = 60
	LN_2 = 40
	LN_3 = 20
	LN_4 = 0
C_3 Sole Rice	N_1 = 90
	N_2 = 60
	N_3 = 30
	N_4 = 0
C_4 = Mungbean (Mb.)	
Cs = Cowpea (Cp.)	

Factor A involves nitrogen fertilizer rates of 90, 60, 30, and 0kg N ha^{-1} for monocropping. At the same time, Nitrogen fertilizer rates for intercropped rice were 60, 40, 20 and 0kg ha^{-1}. The levels of nitrogen fertilizer were adjusted based on the proportion of area occupied by intercropped rice in the field. The phosphorus fertilizer was applied equally in all treatments. The amount of potassium in soil was sufficient for rice and legumes. The legumes were fertilized base on the recommended amount while for rice, N fertilizer was applied base on the levels of nitrogen specified in the treatments.

During planting, upland rice was sown 35 days ahead of legumes in their respective rows. The row ration of intercropping was 4:2 raw ratio which mean 4 rows of rice and two rows of legumes. The number of seed required for each plot were based on the number of rows in each plot. The distance of planting between upland rice were 30cm apart while for legumes is 60cm apart. Pest control was performed when needed and irrigation was done once a week.

The rice was harvested when 85% of the grain in the panicle turned yellowish. After harvesting, the grains were immediately threshed and dried for two tow days. Moisture content of the grains was taken after drying and the yield was calculated based on 14% moisture content. In legumes, the pods were immediately dries and thresh thereafter after harvesting. The moisture content of the seeds after were gathered and the total yield were determined base om 12% moisture content. Harvesting of legume were done at 4 days intervals. An area of 7.2m^2 at the center of the plot was used for yield determination of rice and legumes. Harvesting for rice was done when 85 percent of the grain turn yellow while harvesting of legumes were done when the pod turned yellow to brown. The newly harvested rice and legumes pod were dried to 14 and 12% moisture content for rice and legume respectively. After drying the yield for rice and legumes, 1000-seed weight (for rice) and 100-seed weight (for legumes) were recorded.

Agronomic measurements for both rice and legumes include LAI (leaf area index) using a semi-automatic leaf area meter (Li 3000), DMY (dry matter yield), and LER (land equivalent ratio). For rice, measurement includes the number of days to heading, number of days to harvest, number of filled grains, weight of 1000 seeds, and yield of sole and intercropped rice. For legumes, measurement includes the number of branches per plant, number of pods per plant, number of seeds per pod, the weight of 100 seeds, and seed yield.

Leaf areas index (LAI) was calculated as Yan et al. (2019)

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

Land equivalent ratio (LER) was calculated as defined as (Salinas-Roco et al., 2024)

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

Where: Xi and Y =yield of intercropped component

Seed yield was calculated as

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

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

A_2 = area per plot (7.2m^2)

Yi =seed yield (kg plot^{-1})

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

SMC = Seed moisture content

Xm and Ym =yield of monocrop

Dry matter yield (DMY) was calculated as

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

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

$\mathbf{G_A}$ ground area occupied by the sample

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

RESULTS

Edaphic and Abiotic Characteristic of the Experimental Area

The study was conducted at the University of the Philippines Experimental Area at Los Baňos Laguna Philippines (Fig. 1). The soil in the area has a pH of 5.8 with low percent organic matter (1.84%), and the nitrogen content of the soil was extremely low (0.12%). The available phosphorus and potassium were 26.46 ppm and 1.11 (me/100 g soil), respectively. The CEC of the soil is 28.17 me/100g soil, and the soil texture was clay loam. The daily average rainfall is 147mm, and the maximum range of solar radiation was between 21.04 and 20.10MJ m^{-2} min$^{-,1}$, and the air temperature ranges 29 to 34 degrees Celsius.

Leaf Area Index (LAI) and Dry Matter Yield (DMY) of Rice and Legume Intercropping

The LAE of rice intercropped with legume at varying nitrogen fertilizer is presented in Table 2. Interaction effect between cropping system (CS) and levels of nitrogen (LN) was present. Quantitatively, the LAI of rice intercropped with mungbean were slightly higher than rice intercropped with mungbean and sole rice. The response of rice LAI,

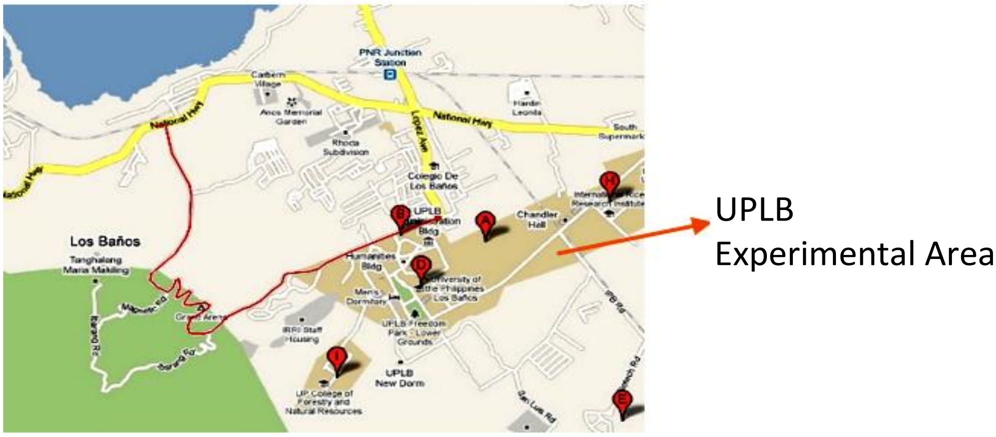

Fig. 1: Location of the study.

Table 2: Leaf area index and dry matter yield of upland rice and legumes intercrop affected by levels of nitrogen (LN) and cropping systems (CS)

Treatment Rice Nitrogen	Upland Rice 60 DAE		Legumes	
Level (kg N ha-1)	LAI	DMY	LAI	DMY
Rice + Cowpea				
60	4.22a	456.51a	3.89c	585.23a
40	4.02a	445.00a	3.85c	576.97a
20	3.29c	285.62cd	3.78c	571.57a
0	2.73cd	115.14f	3.25d	559.25abc
Sole Cowpea	------	------	3.20d	578.14a
Rice + Mungbean				
60	4.35a	369.34b	4.48b	528.24cd
40	4.06a	357.27b	5.26a	528.64cd
20	3.81b	305.72c	3.90c	522.51cd
0	2.34d	12186f	3.84c	513.96d
Sole mungbean	--------	--------	3.86c	516.57d
Sole Rice				
90	4.20a	27377cd		
60	4.00a	263.38cd		
30	2.96cd	214.88e		
0	2.27d	194.11		
C.V.	7.40	9.52	8.84	3.99

DAE (Days after Emergence); Means of the same letter in each column are not significantly different at 5% significant level (DMRT).

in general, increases as LN increases. The maximum LAI in all CS was observed 60 and 40kg N ha^{-1}. Regarding DMY of rice intercropped with legumes at different LN, rice intercropped with cowpea have higher DMY, particularly at 40 to 60kg N ha^{-1}. The 60kg N ha^{-1}, quantitatively have the highest DMY among the CS.

In Legumes, the LAI of intercropped mungbean were significantly high at 20, 40, and 60kg N ha^{-1} compared to intercropped cowpea in their respective LN. In the same table (Table 2), the DMY of sole and intercropped cowpea were significantly higher compare to sole and intercropped mungbean in their respective LN. In general, the LAI of intercropped mungbeans where high while the DMY was high in intercropped cowpea.

Number of Days to Heading

The number of days to heading of sole and intercropped rice is presented in Table 3, unlike LAI and DMY, not interaction effect between CS and LN which means that the response of CS is no affected by the LN fertilizer. Among CS, the days to heading were longer than rice intercropped with either mungbean or cowpea compared to sole crop rice. The LN hastes the sole and intercropped rice heading period when applied with 40kg N ha^{-1} to 60kg N ha^{-1}. The heading stage was delayed in sole and intercropped rice receiving no nitrogen fertilizer.

Days to Maturity

The number of days to maturity covers the period from seedling emergence to harvesting (85% of the panicle turn yellow) is revealed in Table 4. Among the CS, rice intercropped with cowpea has longer maturity period regardless of the LN. The LN significantly affects rice maturity. Rice receiving nitrogen fertilizer at the 60 and 40kg N ha^{-1} matured earlier than rice receiving 20kg N ha^{-1}. The period of maturity was much longer in rice receiving no nitrogen fertilizer.

Table 3: Number of days to heading of monocrop and intercropped rice crop affected by LN and CS

Rice Nitrogen Level	CROPPING SYSTEM			MEAN[2]
(kg N ha^{-1})	Rice[1]	Rice+cowpea	Rice+Mungbean	
60	86.66	90.66	87.00	88.11c
40	83.66	90.00	89.33	87.66c
20	92.33	95.00	92.66	93.33b
0	100.66	101.00	104.33	102.00a
MEAN[3]	90.83b	94.17a	93.24a	

CV - 2.73; [1] Nitrogen levels for monocrop rice were 90, 60, and 30 kg N ha^{-1}; [2] Least Significant Difference (LSD - 0.05) = 2.4657 to compare means of nitrogen levels. Means with the same letters are not significantly different; [3] LSD (0.05) = 2.1354 to compare the means of the cropping system. Means with the same letters are not significantly different.

Filled Grain and Weight of 1000-seed

Table 5 shows the number of filled grains in a panicle of sole and intercropped rice. The data reveals that the number of filled grains in a panicle significantly increases with increasing fertilizer applied regardless of CS. Rice receiving 60kg N ha^{-1} obtained the highest number of filled grains. It is more than 2-time (2.11) higher number of field grain than rice with no nitrogen fertilizer applied. Rice receiving 20 and 40 Kg N ha^{-1} were 59 and 11 percent lower than rice receiving 60Kg N ha^{-1}.

Table 4: Days to maturity of monocrop and intercropped rice affected by different LN and CS

Rice Nitrogen	CROPPING SYSTEN			MEAN[2]
Level (kg N ha^{-1})	Rice [1]	Rice +Cowpea	Rice +Mungbean	
60	120.00	125.33	120.33	121.00c
40	119.33	125.00	120.66	121.88c
20	122.66	128.33	122.66	125.55b
0	125.66	127.33	124.00	128.66a
MEAN[3]	121.91b	126.50a	121.91b	

C.V. 2.22; [1]Nitrogen levels for monocrop rice were 90, 60, and 30 kg N ha^{-1};[2]LSD (0.05) = 2.67 to compare means of nitrogen levels. Means with the same letter are not significantly different; [3]LSD (0.05) = 2.30 to compare means of cropping systems. Means with the same letter are not significantly different.

Table 6 shows the weight of 1000-grain or sole and intercropped rice affects the CS and LN. Interaction effect is not significant, meaning neither nitrogen nor CS influences each other. The weight of 1000-grain of rice is significantly high in rice intercropped with cowpea. The weight of 1000-seed did not change substantially with an increasing amount of nitrogen fertilizer applied, except for sole and intercropped rice that were not applied with nitrogen fertilizer obtained significantly lower 1000-grain weight.

Table 5: Number of filled grain in a panicle of monocrop and intercropped upland rice affected by LN and CS

Rice Nitrogen Level[1] (kg N ha^{-1})	CROPPING SYSTEM			MEAN [2]
	Rice[1]	Rice+Cowpea	Rice+Mungbean	
60	123.33	125.00	144.00	130.77a
40	115.33	117.66	114.66	115.88b
20	61.66	85.33	83.33	76.77c
0	65.66	58.66	61.00	61.78d
MEAN	91.50	96.66	100.75	

C.V. 14.68; [1]Nitrogen levels for monocrop rice were 90, 60, and 30 kg N ha^{-1}; LSD (0.05) = 13.82 to compare means of nitrogen level. Means with the same seeding rate are not significantly different.

Grain Yield (Upland Rice)

Grain yield data of sole and intercropped upland rice are presented in Table 7. The data reveals the interaction effect between CS and LN on the yield of rice. In general, the yield of rice increases with increasing amounts of nitrogen fertilizer. However, the response is not similar between the three CS. The grain yield of sole rice is noticeably higher than that of intercropped rice at any given LN. Among intercrops, rice intercropped with cowpeas receiving 40 and 60kg N ha^{-1} obtained higher grain yield than rice intercropped with mungbean. Between the application of 40 and 60kg N ha^{-1} yield of rice intercropped with cowpea applied with 60kg N ha^{-1} is 13 percent higher compared to 40kg N ha^{-1}. On the other hand, rice intercropped with cowpea applied with 20, 40, and 60kg N ha^{-1}are 63, 45.3, and 58.89 percent respectively higher than rice intercropped with mungbean. Rice intercrop with mungbeans has a lower yield in any given LN parallel to rice intercropped with cowpea.

Table 6: Weight of 1000-seed of monocrop and intercropped upland rice affected by LN and CS

Rice Nitrogen Level[1] (kg N ha^{-1})	CROPPING SYSTEM			MEAN [2]
	Rice[1]	Rice+Cowpea	Rice+Mungbean	
60	22.43	22.99	22.41	22.61a
40	22.61	22.98	22.07	22.55a
20	22.57	22.42	21.80	22.26a
0	21.73	21.69	21.60	21.67b
MEAN[3]	22.33b	22.52a	21.97b	

CV - 2.12; [1]Nitrogen levels for monocrop rice were 90, 60, and 30 kg N ha[1]; [2] LSD (0.05) = 0.4613 to compare means of nitrogen levels. Means with the same letter are not significantly different; [3] LSD (0.05) = 0.3995 to compare means of cropping systems. Means with the same letter are not significantly different.

Number of Branches, Pod per Plant, Seeds per Pod and Weight of 100-Seed of Legumes

Table 8 presents the number of branches, pods per plant, seeds per pod and weight of 100 seeds of sole and intercropped legumes. Statistically, the LN does not significantly influence the measured parameters in sole and intercropped legumes. In the number of branches, sole and intercropped mungbean have more branches than sole and intercropped mungbean regardless of LN. Similar results were observed in the number of pods per plant, wherein sole and intercropped mungbean produces more pods than cowpea. However, since pod of cowpea is a bit longer and bigger than mungbean, the number of seeds per pod and the weight of 100-seed were significantly higher than sole and intercropped mungbean in any LN.

Table 7: Grain yield (kg ha^{-1}) of monocrop and intercropped upland rice affected by LN and CS

Rice Nitrogen Level (kg N ha^{-1})	CROPPING SYSTEM		
	Rice[1]	Rice + cowpea	Rice + Mungbean
60	2,611.11a	1,492.12b	878.70cd
40	2,558.33a	1,319.40b	598.15de
20	1,509.25b	715.74d	451.06e
0	1,015.74c	345.83e	283.9e

C.V. 9.06; [1] Nitrogen levels for monocrop rice were 90, 60, and 30kg N ha; Means in the table with the same letter are not significantly different at 5% significant levels (DMRT).

Table 8: Yield component of monocrop and Intercropped legumes affected by LN and CS

TREATMENT (Rice Nitrogen Lovel kg N ha^{-1})	BRANCH NUMBER (m^4)	POD PER PLANT	SEEDS PER POD	WEIGHT OF 100-SEED (g)
Rice + Cowpea				
60	284,44b	16.67b	12.33a	11.59a
40	248.88b	17.33b	13.00a	10.95a
20	235.55b	16.00b	12.33a	11.39a
0	244.44b	14.33b	12.66a	11.56a
Cowpea	200.00b	14.33b	12.76a	11.66a
Rice + Mungbean				
60	439.99a	46.00a	10.67b	5.41b
40	43110a	45.67a	11.00b	5.67b
20	431.10a	49.33a	11.00b	5.78b
0	359.99ab	44.67a	11.00b	5.63b
Mungbean	386.66a	47.33a	11.33b	5.63b
C.V.	15.47	15.77	6.55	6.52

Means in each column with the same letter are not significantly different at 5% significant level (DMRT).

Seed Yield of Intercrop Legumes

The seed yield of sole and intercropped legumes in Table 9, shows the resilience of mungbean under intercropping system. The yield of sole mungbean is considerably high than when intercropped. Comparing intercropped mungbean and cowpea, the yield of intercropped mungbean is significantly higher than intercropped cowpea regardless of LN.

Land Equivalent Ratio

Table 9 presents the productivity of an area in terms of land equivalent ratio (LER). The highest LER was attained be rice intercropped with cowpea at 60 kg N ha^{-1}. These were followed by the value of LER receiving 40 and 20kg N ha^{-1}. The LER value of rice intercropped with mungbean applied with 60, 40, and 20kg N ha^{-1} were significantly low at any LN. The LER ratio of 1.26 indicates the intercropping of upland with cowpea in 26 more productive than planting alone.

DISCUSSION

Cropping System (Intercropping)

Intercropping is the planting of two or more crops simultaneously in the same field. One of this research's primary objectives of this research is to determined

Table 9: Yield of legumes land equivalency ration of intercropping

TREATMENT Rice Nitrogen Level (kg N ha^{-1})	YIELD (kg ha^{-1})	LER
Rice + Cowpea		
60	672.87c	1.26a
40	629.31c	1.16b
20	534.31c	1.16 b
0	602.36c	0.98c
Cowpea	979.26b	1.00c
Rice + Mungbean		
60	819.54b	0.99c
40	804.26b	0.90c
20	830.79b	1.00c
0	831.99b	0.95c
Mungbean	1232.59a	1.00c
C.V.	11.15	10.34

Means with the same letter are not significantly different at 5% significant level (DMRT).

suitable legume that complement the upland rice's growth and yield. Farmers give more priority to upland rice over the other crops in the intercropping system. The decision to focus on rice production stems from its essential role in meeting their families' dietary needs and securing a reliable food source (Zapico et al., 2020). In this study, the term "intercropping" is refined into "complementary intercropping". According to Maitra et al. (2021) complementary intercropping is an approach that involves a deep understanding of ecological principles to create a system where crops enhance each other's growth and productivity. In reverts, there are also crops that have aggressively growth when used as intercrop. Aggressive growth signifies a scenario where one crop species within the system exhibits a disproportionately high rate of growth, leading to it dominating and potentially suppressing the growth of the other intercropped species and, it can be measured using LER (Kaiira et al., 2024). Rice intercropped with mungbean significantly reduced the rice yield but elevated the yield of mungbean regardless of the nitrogen levels. The reduction in the yield of rice is greater than the reduction in the yield of mungbean. For instance, if the yield of monocrop and intercropped mungbean applied with 60kg N ha^{-1} (Table 8) is subtracted, the difference would be 413.05kg ha^{-1}. But when the yield of monocrop and intercropped rice applied with 60kg N ha^{-1} (Table 6) is subtracted, the difference would be 1,732.41kg ha^{-1} a huge difference. The LER of rice intercropped with mungbean was 0.99, which indicates that intercropping of the said combination is not productive, about 66.35% reduction when rice intercropped with mungbean at 60kg N ha^{-1}. The higher LAI (Table 2) and number of branches (Table 8) of intercropped mungbean, at 60kg N ha^{-1} contributes to the low 1000-seed weight (Table 6) and poor grain yield of rice intercropped with mungbean (Table 7). The results were attributed to the aggressive growth habit of mungbean, which causes pressure in the growth and yield of rice (Maitra et al., 2021). Parallel research has shown that 1000-seed weight of rice intercropped with soybean, ground nut and beans was significantly reduced (Kaiira et al., 2024). The researcher also reported a reduction teller and panicles per m^2 of intercropped rice. The legume component yield components such as a number of pods and weight of 100 seeds were not affected by intercropping. Papong et al. (2020) also observed, that intercropping upland rice var. Zambales with mungbean have the low weight of panicle per $0.5m^2$, number of filled grains per panicle and low productive tiller compared to upland rice intercropped with peanut. The research output of Wangiyana et al. (2023) reveals the opposite result, wherein the LER is 1.27 of rice intercropped with mungbean. Additionally, the researcher furthered that rice-mungbean intercropping at a 2:2 row ratio, significantly has high numbers of green leaves, tillers, panicles and filled grains per clump.

Rice intercropped with cowpea obtained a LER of 1.26 at 60kg N ha^{-1}; the yield reduction of cowpea due to intercropping was 42.85 percent, which is 23.5 percent lower compared to rice intercropped with mungbean. The LAI (Table 2) and the 1000-seed weight (Table 6) of rice intercropped with cowpea were higher than rice intercropped with mungbean. On the other hand, cowpea, as a counterpart to rice, has quantitatively less LAI but is high in dry matter. Those qualities are important under intercropping conditions because they complement with the growth of in component crops.

Levels of Nitrogen

Nitrogen fertilizer is crucial for upland rice because it significantly enhances growth, yield, and productivity. This study shows the response of intercropped upland rice supplied with different nitrogen levels (LN). This study has a positive response on the productivity, yield and yield component of sole and intercropped upland rice. The results show that productivity of intercropping varies depending on which legume used for intercropped with upland rice and the LN fertilizer supplied to rice. The aggressive growth habit of mungbean was already discussed in the cropping system. In that, the productivity of rice intercropped with mungbeans, which is represented by LER value, was 1 or less, no matter how much LN fertilizer applied to intercropped rice. On the other side, intercropping cowpea complements the growth of the rice component. Hence, the LER of rice intercropped with legumes increases with increasing LN applied. According to Hussain et al. (2022), increasing the amount of nitrogen fertilizer can enhance the productivity of upland rice, but only up to an optimal level.

In parallel, the study shows that the incremental increase of the LN applied also increased the LER of the intercrop. The maximum LN of 60 kg N ha^{-1} provides an LER value of 1.26 percent (Table 9), which indicates that intercropping is 26% more productive than the sole monocrop. The yield of each component in the intercropping system influences the LER value. Intercropped cowpeas do not significantly respond to increasing LN applied to rice. However, the sole and intercropped upland rice increases with increasing LN applied up to 40 kg N ha^{-1}. Further increased the LN to 60 kg N ha^{-1}, the increase in rice yield is no longer significant. Economically, the application of 60 kg N ha^{-1} would yield 172 kg additional yield, so this increase is tantamount to cover additional expenses. According to (Salinas-Roco et al., 2024), nitrogen fertilization can enhance the grain yield of cereal crops in intercropping systems, leading to a higher LER. This is because cereals often respond positively to additional nitrogen, increasing their productivity. The increase in yield with increased nitrogen is supported by Salinas-Roco et al. (2024), saying that nitrogen fertilization can enhance the grain yield of cereal crops in intercropping systems, leading to a higher LER. This is because cereals often respond positively to additional nitrogen, increasing their productivity.

The yield components of rice play a crucial role in determining overall productivity. In this study, key yield components evaluated included the number of days to heading, days to maturity, and the number of filled grains. The number of days to heading indicates the duration required for upland rice to reach its reproductive phase, marking the shift from vegetative to reproductive growth, characterized by the emergence of the panicle from the rice stem. Days to maturity refers to the time span from seedling emergence until approximately 85% of the grains in the field turn yellow, indicating physiological maturity. The results (Table 3 and 4) show that rice plants receiving nitrogen at rates of 40 and 60 kg N ha^{-1} reached heading and maturity earlier than those receiving 0 or 20kg N ha^{-1}. This finding is consistent with previous studies by Hussain et al. (2022) and Yun et al. (2023), which reported that adequate nitrogen availability accelerates the transition to the reproductive stage. Furthermore, sufficient nitrogen enhances grain filling efficiency, thereby promoting earlier maturity (Zhang et al., 2020).

The number of filled grains in a panicle increases with an increasing amount of nitrogen, whereas, rice applied with 60kg N ha^{-1} obtained the highest number. This result was supported by Hu et al. (2024) who said that adequate nitrogen supply enhances the photosynthetic capacity of plants. High photosynthesis rates mean more carbohydrates are produced, supporting grain production (Zhao et al., 2022). Finally, the LAI and the DMY of rice were significantly high in sole and intercropped upland rice (Table 2). Studies have shown that the LAI at specific growth stages significantly affects yield components like grain number per panicle and 1000-grain weight Hussain et al., (2022). Additionally, dry matter production during key stages, such as heading and harvesting, is crucial for achieving high yields (Hashimoto et al., 2023).

Conclusion

The study concludes that intercropping upland rice with cowpeas, combined with the application of 60 kg N ha^{-1}, is the most effective strategy for maximizing rice yield and land use efficiency. This treatment produced the highest rice yield, reaching 1,492kg ha^{-1}, and resulted in a 26% increase in the land equivalent ratio (LER = 1.26) compared to the sole cropping of rice. The presence of cowpeas positively influenced rice growth by improving key yield attributes, including the number of filled grains per panicle and the 1000-seed weight. In contrast, intercropping with mungbeans, despite producing a higher mungbean yield, negatively impacted rice performance due to excessive shading from the vigorous growth habit of mungbean plants. This led to a reduced rice yield of 878.70kg ha^{-1} and a lower LER of 0.99. Overall, the findings suggest that cowpeas are a more compatible and beneficial legume species for intercropping with upland rice under the studied conditions.

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Ethical Compliance: 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 and analysis, writing, and manuscript preparation.

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