SVU-IJAS SVU-International Journal of Agricultural Sciences
Volume 6 Issue (1) pp.: 168-189, 2024
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2024.275733.1351
RESEARCH ARTICLE

Response of upland rice (*Oryza sativa* L.) variety NSIC Rc27 TO intercropping scheme at different sowing time of mungbean (*Vigna radiata* L.) intercrop

Labrador, J.A.[1], D.M. Bañoc [1]*, A.G. Luz [1] and K.L.P. Yap [2]

[1] *Department of Agronomy, Visayas State University (VSU), Visca, Baybay City, Leyte, Philippines.*
[2] *Department of Agricultural Education and Extension, Visayas State University (VSU), Visca, Baybay City, Leyte, Philippines.*

Abstract

The intercropping system stands as a prevalent strategy for augmenting crop yield. To test the mentioned system, a study was conducted to evaluate the impact of intercropping systems and mungbean sowing time on upland rice using the NSIC Rc27 variety under different mungbean sowing times. The experiment was laid out in Randomized Complete Block Design (RCBD) using a split-plot arrangement with three replications, intercropping systems were distributed in the main plots while the sowing time of mungbean plants was arranged in sub-plots. Results showed that the tested factors and their interaction did not have significant effects on leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), and yield components for both upland rice and mungbean. On the other hand, notable variations were observed in weed parameters, agronomic characteristics, and grain yield of both crops. Monocropping and early mungbean sowing time (14 days before upland rice establishment) led to early flowering but delayed maturity in upland rice. The land and area-time equivalent ratios were greater than one, indicating that both crops can be grown together, wherein simultaneous planting was the most effective treatment. The intercropping scheme resulted in a lower weed population. Monocropping upland rice yielded a net profit of PhP38,425 while intercropping with mungbean 14 days before upland rice establishment resulted in a higher net profit of PhP70,325. Similarly, monocropping mungbean yielded PhP197,175.00 while intercropping with upland rice 14 days earlier produced the highest net profit of PhP283,575.

Keywords: Area time equivalent ratio; land equivalent ratio; upland rice; mungbean; sowing time.

1. Introduction

Rice (*Oryza sativa* L.) is renowned for its adaptability, thriving in diverse environments ranging from uplands to lowlands. Its global significance as a staple food underscores its pivotal role in agriculture. In the Philippines and other ASEAN countries, where rice is a dietary staple, upland rice production has gained importance due to the decreased availability of lowland areas for farming. Rao *et al.* (2017) highlight the need for innovative, resource-efficient, profitable, and environmentally friendly rice farming systems in uplands to ensure sustainability and a consistent supply. Efficient cropping systems are vital to overcome limitations in upland rice cultivation, especially in areas facing soil nutrient deficiencies and degradation.

Intercropping, particularly the combination of upland rice with mungbean, presents a promising solution. This approach can rejuvenate degraded uplands, improve soil fertility, and enhance farming system resilience to climate

***Corresponding author: D.M. Bañoc**
Email: dionesio.banoc@vsu.edu.ph
Received: March 9, 2024; Accepted: March 26, 2024; Published online: March 30, 2024.

uncertainties. Mungbean's nitrogen-fixing ability makes it an excellent intercrop choice, positively influencing the main crop's growth. Favero *et al.* (2021) and Saeed *et al.* (1999) emphasize the potential for increased overall crop production through the integration of mungbean with upland rice. However, challenges such as nutrient competition, management complexity, and pest susceptibility hinder the broader acceptance of intercropping, as noted by Huss *et al.* (2022).

To address these challenges, the strategic timing of mungbean intercrop sowing is crucial. Varying the sowing time benefits both upland rice and mungbean, optimizing growth conditions for upland rice while utilizing mungbean's shading resilience in intercropping. This approach aims to create favorable conditions for upland rice growth while identifying the best sowing period for mungbean. Thus, this study investigates the timing complexities of the mungbean intercrop to optimize coexistence and productivity in the intercropping framework.

2. Materials and Methods

The study was conducted in the Experimental Field of the Department of Agronomy, Visayas State University, Visca, Baybay City, Leyte, Philippines, from April 7 to August 5, 2023 (Table 1). A 759 m^2 area was prepared by plowing and harrowing twice weekly using a tractor to ensure soil pulverization, weed removal, and optimal seed germination conditions. Drainage was established around the experimental area and between replications to prevent water logging during heavy rainfall. Ten soil samples were randomly collected from the experimental area at a depth of 30 cm before crop establishment. These samples were combined, air-dried, pulverized, and sieved using a 2.0 mm wire mesh. They were then submitted for analysis of soil pH, organic matter content, total nitrogen, available phosphorus, and exchangeable potassium at the Central Analytical Services Laboratory PhilRootCrops, Visayas State University, Visca, Baybay City, Leyte, Philippines.

The experiment was laid in a randomized complete block design using a split-plot arrangement with three replications. The main plot was the intercropping scheme, while the subplot was the sowing time of the mungbean intercrop. The cropping system scheme included upland rice monocropping (M_1), mungbean monocropping (M_2), and upland rice + mungbean intercropping (M_3). Mungbean sowing time was designated as S_1 (14 days before upland rice establishment), S_2 (7 days before upland rice establishment), S_3 (simultaneous planting), S_4 (7 days after upland rice establishment), and S_5 (14 days after upland rice establishment). The mungbean intercrop was sown on April 7, 2023, for S_1; April 14 for S_2; April 21, 2023, for S_3; April 28, 2023, for S_4; and May 5, 2023, for S_5. An alleyway of 1.0 m between replications and 0.50 m between treatment plots was made to facilitate data gathering and management.

Air-dried chicken manure from Larrazabal farm, Ormoc City, Leyte Philippines, was analyzed at the Central Analytical Service Laboratory, PhilRootcrops, Visayas State University, Visca Baybay City, Leyte. Results showed a pH of 8.88, 11.28% organic matter, 2.84% total nitrogen, 1.38 mg kg available phosphorus, and 4.91 mg kg^{-1} exchangeable potassium. The manure displayed strong alkalinity, high organic matter, and nitrogen content, and low phosphorus and exchangeable potassium levels. It was applied at a rate of five tons per hectare three weeks before planting the main crop, following methods similar to Adekiya and Agbede (2017).

Fermented pseudo-stem banana extract mixed with molasses (2:1 ratio) was applied to plant leaves, growing points, and soil around upland rice during its reproductive stage. The fermented extract contained 0.12% total nitrogen, 0.44% available phosphorus, and 1.79% exchangeable potassium, indicating relatively low levels of organic matter and nitrogen, as well as limited phosphorus and exchangeable potassium content.

The study utilized the upland rice NSIC Rc27 variety and the Pag-asa 19 variety for mungbean. The planting distance adopted was 0.25 m x 0.25 m for upland rice monoculture and upland rice-mungbean intercropping, following the method outlined in the study by Alogaidi et al. (2019). For mungbean monoculture, the planting distance was 0.50 m between furrows with 15 plants per linear meter. Plant counts were 192 for upland rice monoculture, 360 for mungbean monoculture, and 192 + 360 for mungbean in the upland rice-mungbean intercropping scheme. Hand weeding was employed for controlling weeds.

Data collected included days to flowering and maturity, leaf area index calculated by multiplying the length and width of each leaf from the middle tiller and adjusting with a correction factor and dividing by the ground area covered by ten sample plants, crop growth rate quantifying dry matter production increase per unit land area over time, land equivalent ratio computed by comparing poly-culture yield to monoculture yields on the same land area, area time equivalent ratio calculated by dividing total yield by land area used multiplied by time taken, and grain yield (t/ha) determined by dividing total harvested grain weight by land area, providing yield per unit area for upland rice and mungbean, along with weed parameters. Meteorological data, such as total weekly rainfall, minimum and maximum temperatures, and relative humidity, were sourced from the Philippine Atmospheric Geophysical and Astronomical Services (PAGASA) Station, VSU, Visca, Baybay City, Leyte, Philippines. Analysis of variance (ANOVA) was conducted using a Statistical Analysis System (SAS version 9.0), with Honestly Significant Difference (HSD) used for comparing treatment means.

3. Results and discussion

Meteorological data, sourced from the PAGASA Station at Visayas State University, Visca, Baybay City, Leyte, Philippines, revealed a total rainfall of 254.41 mm during the study period, with the highest in June (130.88 mm) and the lowest in April (5.70 mm) (Fig. 1). Weekly rainfall ranged from 1.14 mm to 32.67 mm from upland rice planting (week 1) to harvesting (week 19), indicating inadequate moisture for upland rice growth. To address moisture stress conditions, intermittent watering was applied when dryness occurred. Average maximum and minimum temperatures were 30.37 °C and 25.93 °C, respectively, falling within the optimal range for rice and mungbean growth. The average relative humidity of 78.87% also supported rice cultivation. Mungbean seeds germinated in 2-3 days, while upland rice took 7-10 days in all treatments. Bird infestations affected both crops, leading to the adoption of strict cultural management practices such as metallic strings and scarecrows. Stem borer infestation occurred during the vegetative stage of upland rice in monocropping treatments (M_1), prompting the application of Karate (5EC) and fermented banana extracts during various growth stages of both crops.

3.1. Soil Chemical Properties

Table 1 displays soil test results before planting and after upland rice harvest as influenced by intercropping scheme and mungbean sowing time. Initially, soil pH was 6.25, with 1.068% organic matter, 0.113% total nitrogen, 95.700 mg kg^{-1} available phosphorus, and 241.410 mg kg^{-1} exchangeable potassium. These indicate slightly acidic soil with low organic matter and nitrogen but high phosphorus and exchangeable potassium levels. The final soil analysis revealed a shift from slightly to moderately acidic pH, influenced by nutrient uptake rates of different crops and nitrogen transformations.

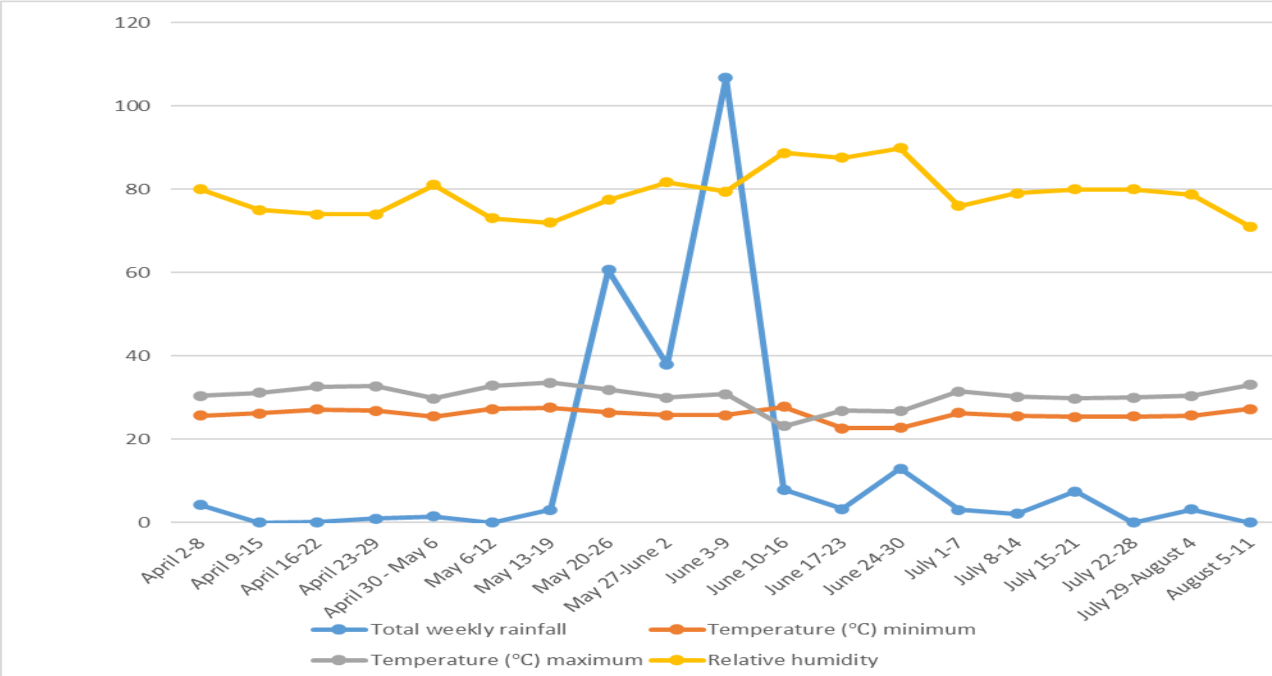

Figure 1. Total weekly rainfall (mm), average weekly minimum and maximum temperatures (°C), and relative humidity throughout the experiment from April 1 to August 11, 2023, obtained from the Philippine Atmospheric Geophysical and Astronomical Services (PAGASA) Station, Visayas State University (VSU), Visca, Baybay City, Leyte, Philippines

Table 1. Soil test results before planting and after harvest of upland rice (O*ryza sativa* L.) var. NSIC Rc27 to the intercropping scheme at different sowing times of mungbean *(Vigna radiata* L.) intercrop.

Soil Analysis	Soil pH	OM (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable K (mg/kg)
Initial	6.25	1.068	0.113	95.700	241.410
Final					
M_1- Upland rice monocropping					
S_1	5.83	1.224	0.112	127.90	295.76
S_2	5.95	1.218	0.107	122.90	269.83
S_3	6.05	1.267	0.127	124.90	274.61
S_4	5.97	1.193	0.110	105.00	267.40
S_5	5.95	1.206	0.110	131.50	306.05
Mean	5.95	1.222	0.113	122.44	282.73
M_2- Mungbean monocropping					
S_1	6.00	1.310	0.118	108.10	326.43
S_2	6.07	1.304	0.127	148.40	301.91
S_3	6.05	1.377	0.121	203.20	389.35
S_4	6.02	1.408	0.130	145.90	289.63
S_5	6.05	1.310	0.115	137.70	313.69
Mean	6.04	1.342	0.122	148.66	324.02
M_3- Upland rice + Mungbean intercropping					
S_1	5.99	1.248	0.098	136.50	241.89
S_2	5.94	1.261	0.078	125.70	326.47
S_3	5.95	1.328	0.147	119.00	282.15
S_4	5.74	1.279	0.118	110.00	312.98
S_5	6.13	1.101	0.144	128.70	341.64
Mean	5.95	1.243	0.117	123.98	301.03

While organic matter content increased but remained at a lower level. Total nitrogen levels were consistent across treatments, aided by mungbean's nitrogen-fixing ability. Balancing nitrogen mineralization and immobilization processes is crucial. Phosphorus and potassium levels significantly increased post-planting, positively impacting plant growth. Rainfall and temperature were key in enhancing nutrient movement and activating soil microbes. Alterations in soil pH were noted to affect nutrient availability, potentially influencing nutrient solubility and mobility (Gupta and O'toole, 1986; Gworek *et al.*, 2021; Grzyb *et al.*, 2021).

3.2. Agronomic Characteristics of Upland Rice (NSIC Rc27)

No significant differences were observed in plant height and the number of days from sowing to heading of upland rice. Significant variations were found in several characteristics of upland rice, including days from sowing to flowering and maturity, fresh straw yield, leaf area index, crop growth rate, land and area time equivalent ratios, grain yield, and weed parameters as influenced by intercropping scheme and mungbean sowing time (Table 2 and Figures 2 & 3).

No significant differences were observed in the plant height of upland rice based on intercropping and mungbean sowing time. Monocropping of upland rice (M_1) exhibited greater height than intercropping (M_3).

Table 2. Agronomic characteristics of upland rice (*Oryza sativa* L.) var. NSIC Rc27 as influenced by intercropping scheme and time of sowing of mungbean (*Vigna radiata*) intercrop

Treatment	Number of days from sowing to			Plant height (cm)	Fresh straw yield (ton/ha)
	Flowering	Heading	Maturity		
Intercropping scheme					
M_1 = Monocropping upland rice	75.60^{ab}	69.60	98.67^{a}	89.18	25.63^{a}
M_3 = Intercropping system (upland rice)	77.93^{ab}	70.13	96.20^{ab}	81.57	15.12^{b}
Mean	76.77	69.87	97.44	85.37	20.38
Time of planting of mungbean intercrop					
S_1	71.84^{b}	66.83^{b}	99.00^{ab}	83.39	25.86^{a}
S_2	80.17^{ab}	69.83^{b}	100.84^{ab}	84.48	19.32^{b}
S_3	74.50^{b}	68.83^{b}	96.67^{abc}	81.21	19.29^{b}
S_4	74.00^{b}	65.17^{b}	95.67^{abc}	78.36	17.58^{b}
S_5	83.33^{a}	78.67^{a}	95.00^{bc}	99.43	19.86^{b}
Mean	76.77	69.87	94.44	85.37	20.38
IS x TPI	**	ns	**	ns	ns
CV (a) %	4.13	3.85	1.60	23.52	29.36
CV (b) %	4.01	5.79	3.38	23.59	12.66

The means within a column with the same letter and those without letter designations are not significantly different at the 5% level, based on HSD.

This might be due to the inter-specific competition and intense intraspecific competition among densely planted mungbean, limiting resources for upland rice. Higher plant density increases resource competition, affecting upland rice growth. Intercropped mungbean alters microclimate and canopy structure. The result aligns with the findings of Sa Xiao *et al.* (2006), which indicate decreasing plant height with increasing population density. This result contrasts with the finding that higher plant densities led to taller plants (Olsen and Weiner, 2007; Ciampitti and Vyn, 2011; Rossini *et al.*, 2011). Moreover, no significant difference in upland rice height was observed with varying mungbean sowing times. Planting mungbean 14 days after upland rice (S_5) resulted in taller upland rice which attributed to reduced competition for resources.

Delayed flowering in upland rice in intercropping (M_3) compared to monocropping (M_1) suggests intercrop influence on flowering dynamics. Despite the delay, upland rice in the intercropping scheme achieved earlier maturity without significantly prolonging the crop cycle. Variations were observed in days to flowering, heading, maturity, and fresh straw yield of upland rice with varying sowing times of the mungbean intercrop. Monocropping and intercropping of mungbean 14 days before upland rice (S_1) resulted in early flowering for both crops. In contrast, intercropping mungbean 14 days after upland rice (S_5) delayed their flowering performance. Optimal timing appears to be planting mungbean intercropped 14 days before upland rice, avoiding negative impacts on upland rice's flowering and heading (Rafiuddin *et al.*, 2021; Saban, 2007).

Significant interaction differences in straw yield were observed due to the intercropping scheme and mungbean sowing times (Fig. 2). Upland rice under monocropping achieved the highest straw yield, surpassing plants under the intercropping scheme. Specifically, sowing mungbean 14 days before upland rice (S_1) resulted in a higher fresh straw yield than other treatments. In monocropping, upland rice avoids inter-specific competition, utilizing resources more efficiently. Sowing mungbean before upland rice establishes a complementary growth pattern, optimizing resource utilization and fostering independent growth for both crops. This timing strategy contributes to the increased herbage yield of upland rice.

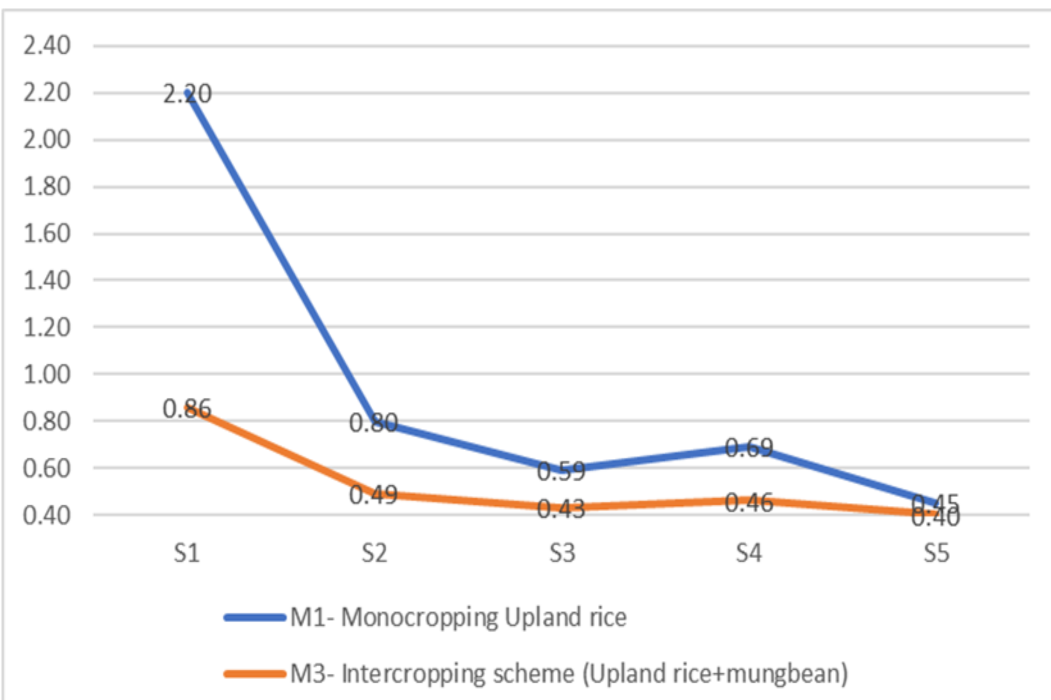

Figure 2. Interaction on several days from sowing to the flowering of upland rice (*Oryza sativa* L.) var. NSIC Rc27 as influenced by intercropping scheme and time of sowing of mungbean (*Vigna radiata* L.) intercrop.

There was a significant interaction observed at the 0.05 level regarding the number of days from sowing to flowering and maturity of upland rice as influenced by intercropping scheme and mungbean sowing times (Fig. 3). Monocropping (M_1) exhibited early flowering and longer maturity periods compared to intercropping systems, indicating a potential correlation between intercropping strategies and flowering patterns. The shortest flowering time (2.20) was observed in S_1, while S_3, S_4, and S_5 had notably longer flowering times. For the number of days from sowing to maturity, S_5 matured earlier than other treatments. Overall, intercropping systems positively reduced upland rice flowering time compared to monocropping. The observed variability highlights the importance of carefully selecting intercropping strategies to optimize upland rice flowering. The result aligns with the findings by Cagasan and Amarado (2023), where peanuts planted two weeks ahead of upland rice resulted in earlier flowering compared to other intercropping sowing times.

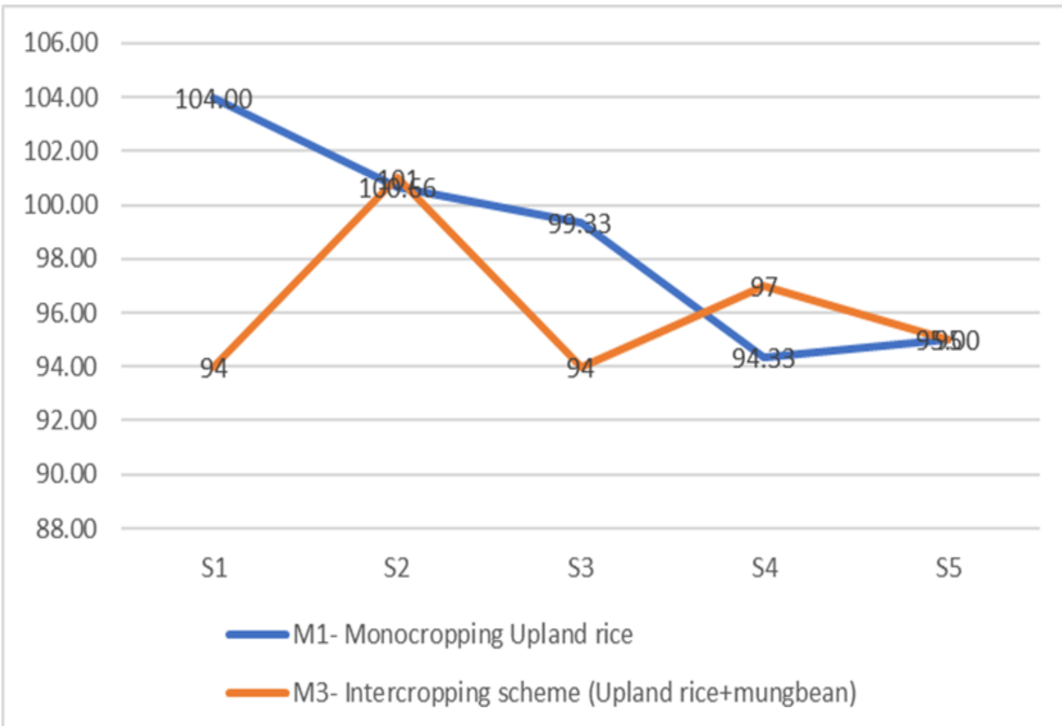

Figure 3. Interaction on several days from sowing to maturity of upland rice (*Oryza sativa* L.) var. NSIC Rc27 as influenced by intercropping scheme and time of sowing of mungbean (*Vigna radiata* L.) intercrop.

3.3. Agronomic Characteristics of Mungbean (Pag-asa 19)

No significant differences were observed in the number of days from sowing to flowering and maturity, plant height, and herbage yield of mungbean (Table 2.1). Mungbean demonstrates adaptable growth in various intercropping schemes, with the intercropping system (M_3) outperforming monocropping (M_2) in plant height and herbage yield due to a diverse canopy structure optimizing light interception and minimizing intra-specific competition (Manasa et al., 2018). Observations revealed variations in mungbean growth impacted by the timing of mungbean intercropping. Planting mungbean 14 days after upland rice establishment (S_5) led to delayed flowering, maturity, and reduced plant height, suggesting heightened nutrient competition, in line with the competitive production principle (Vandermeer, 1989). No significant differences were observed in mungbean's herbage yield with varying intercropping schemes and mungbean sowing times. However, intercropping system M_3 outperformed sole cropping, likely due to the resource complementarity of upland rice and mungbean, efficiently utilizing soil nutrients and resulting in a higher overall herbage yield (Andersen *et al.*, 2004).

Table 2.1. Agronomic characteristics of mungbean (var. Pag-asa 19) as influenced by intercropping scheme and time of sowing of mungbean intercrop

Treatment	Number of days from sowing to		Plant height (cm)	Herbage yield (ton/ha)
	Flowering	Maturity		
Intercropping scheme				
M_2= Monocropping of mungbean	38.80	61.73	84.46	28.80
M_3 =Intercropping system (mungbean)	38.93	61.87	87.33	30.07
Mean	38.87	61.80	85.88	29.43
Time of planting of mungbean intercrop				
S_1	36.00[d]	59.00[b]	86.63[a]	30.17
S_2	37.33[c]	59.00[b]	87.11[a]	28.34
S_3	40.00[b]	61.00[b]	86.43[a]	28.00
S_4	38.00[c]	64.83[a]	91.10[a]	32.83
S_5	43.00[a]	65.17[a]	78.12[b]	27.83
Mean	38.87	61.80	85.88	29.43
IS x TPI	ns	ns	ns	ns
CV (a) %	0.94	5.02	3.86	13.43
CV (b) %	1.88	3.47	5.82	15.14

3.4. Leaf area index and crop growth rate of upland rice variety NSIC Rc27

Yang *et al.* (2012) underscore the importance of leaf area index (LAI) and crop growth rate (CGR) in rice cultivation. The researchers highlighted that upland rice monocropping (M_1) exhibits wider LAI and higher CGR which is attributed to larger leaves thriving in increased light conditions (Price and Munns, 2016). Monocropping facilitates enhanced photosynthesis, whereas intercropping (M_3) may impede sunlight, thereby affecting leaf expansion. Marler (1994) and Fischer (1975) accentuate light's crucial role in rice growth. In the intercropping scheme, mungbean's LAI and CGR are shaped by a modified microclimate (Setiawan, 2022), promoting physiological processes and resource efficiency (Rasmussen and Schmidt, 2022). Reduced intraspecific competition in intercropping fosters mungbean growth, leading to a higher leaf area.

No significant differences were found in the Leaf Area Index (LAI) or Crop Growth Rate (CGR) across upland rice treatments (Table 3). However, planting mungbean seven days after upland rice (S_4) resulted in the smallest LAI, potentially delaying flowering and tasseling in upland rice. Conversely, sowing mungbean intercropped 14 days before upland rice establishment (S_1) led to higher CGR. This temporal resource mismatch resonates with Craine and Dybzinski's (2013) study, highlighting the complexities of resource competition across time, space, and species. Intercropping mungbean 14 days before upland rice (S_1) promotes a more harmonious resource utilization, facilitating wider LAI and higher CGR development.

Table 3. Leaf area index and crop growth rate of upland rice (*Oryza sativa* L.) var. NSIC Rc27 as influenced by the intercropping scheme and time of sowing of mungbean (*Vigna radiata* L.) intercrop.

Treatment	Leaf area index (LAI)	Crop growth rate (CGR)
Intercropping scheme		
M_1 = Monocropping upland rice	0.04	0.34[a]
M_3 = Intercropping system (upland rice)	0.03	0.16[b]
Mean	0.04	0.25
Time of planting of mungbean intercrop		
S_1	0.04	0.32[a]
S_2	0.04	0..26[b]
S_3	0.04	0.24[bc]
S_4	0.03	0.21[c]
S_5	0.04	0.23b[c]
Mean	0.04	0.25
IS x TPI	ns	ns
CV (a) %	26.19	15.30
CV (b) %	17.80	11.51

3.5. Leaf area index and crop growth rate of mungbean var. Pag-asa19

The study revealed consistent mungbean leaf area index and crop growth rate across intercropping schemes, indicating uniform leaf area production regardless of intercropping method (Table 3.1). Intercropping (M_3) demonstrated the highest leaf area index, possibly due to complementary resource utilization, where different crops exploit distinct niches for nutrient uptake, sunlight interception, and water use. Conversely, monocropping (M_1) exhibited a higher crop growth rate, likely reflecting reduced intra-species competition. Intercropping environments, as highlighted by Li et al. (2020), foster increased leaf area through facilitative interactions such as shade provision, nitrogen fixation, or soil structure improvement. In contrast, monocropping may prioritize individual growth without such collaborative benefits. Intercropping with legumes like mungbean benefits from nitrogen fixation, supporting leaf development, whereas monocropping may rely more heavily on soil nitrogen, potentially impacting growth rate.

Table 3.1. Leaf area index and crop growth rate of mungbean influenced by intercropping scheme and time of sowing of mungbean (*Vigna radiata* L.) intercrop.

Treatment	Leaf area index (LAI)	Crop growth rate (CGR)
Intercropping scheme		
M_2 = Monocropping mungbean	2.35	0.21
M_3 =Intercropping system (mungbean)	2.52	0.19
Mean	2.44	0.20
Time of planting of mungbean intercrop		
S_1	2.21[b]	0.18
S_2	2.50[ab]	0..18
S_3	2.75[a]	0.23
S_4	2.35[b]	0.23
S_5	2.38[b]	0.19
Mean	2.44	0.20
IS x TPI	ns	ns
CV (a) %	12.68	26.48
CV (b) %	11.44	29.40

Significant variations were noted in mungbean intercropping's leaf area index (LAI) based on sowing time, while no notable differences were observed in crop growth rate (CGR). Simultaneous planting (S_3) resulted in a wider LAI, consistent with Addo-Quaye's (2011) findings, suggesting higher LAI, CGR, and net assimilation rate (NAR) with simultaneous or preceding soybean planting. The early introduction of mungbean into upland rice theoretically lengthens the overlap period and shading. However, maximum overlap benefits from mungbean's vegetative growth phase completion before upland rice reaches peak LAI, as noted by Nouri and Reddy (1991).

3.6. Land and area equivalent ratio of upland rice

The sowing time of mungbean significantly impacted upland rice Land Equivalent Ratio (LER), with simultaneous planting (S_3) yielding the highest LER and ATER (Table 4). However, sowing mungbean 14 days before upland rice (S_1) resulted in the lowest LER. Similar findings by Worku (2014) showed greater partial LERs for mungbean with simultaneous planting. Significant interactions at the 0.05 level were observed on LER and ATER of upland rice affected by mungbean sowing time (Fig. 4). ATER and LER values in Table 7 indicate that simultaneous planting or planting mungbean seven to 14 days after establishing upland rice resulted in higher ATER and LER for upland rice. This suggests a more accurate representation of intercropping benefits in terms of yield, considering the timing of each crop's presence on the same field.

The highest ATER (2.55) was recorded with simultaneous planting, followed by mungbean sown seven days after upland rice establishment (S_4) with 2.33, and 14 days after upland rice establishment (S_5) with ATER of 2.14. The lowest ATER (1.38) occurred when mungbean was sown seven days before upland rice (S_2). In contrast, mungbean that was planted 14 days before upland rice achieved an ATER of 1.15. This variability aligns with findings from other studies by Mandal *et al.* (1990), Tsay *et al.* (1998) and Addo-Quaye (2011) on how different sowing times of intercropped crops significantly affect leaf area index (LAI), crop growth rate (CGR), and net assimilation rate (NAR).

Table 4. Land equivalent ratio and area time equivalent ratio of upland rice (*Oryza sativa* L.) var. NSIC Rc27 as influenced by intercropping scheme and time of sowing of mungbean (*Vigna radiata* L.) intercrop

Treatment	Land equivalent ratio (LER)	Area time equivalent ratio (ATER)
Time of planting of mungbean intercrop		
S_1	1.29c	1.15^{b}
S_2	1.48^{bc}	1.38^{b}
S_3	2.04^{a}	2.55^{a}
S_4	1.92^{a}	2.33^{a}
S_5	1.84^{ab}	2.14^{a}
Mean	1.71	1.91
TPI	**	**
CV (a) %	11.41	13.75

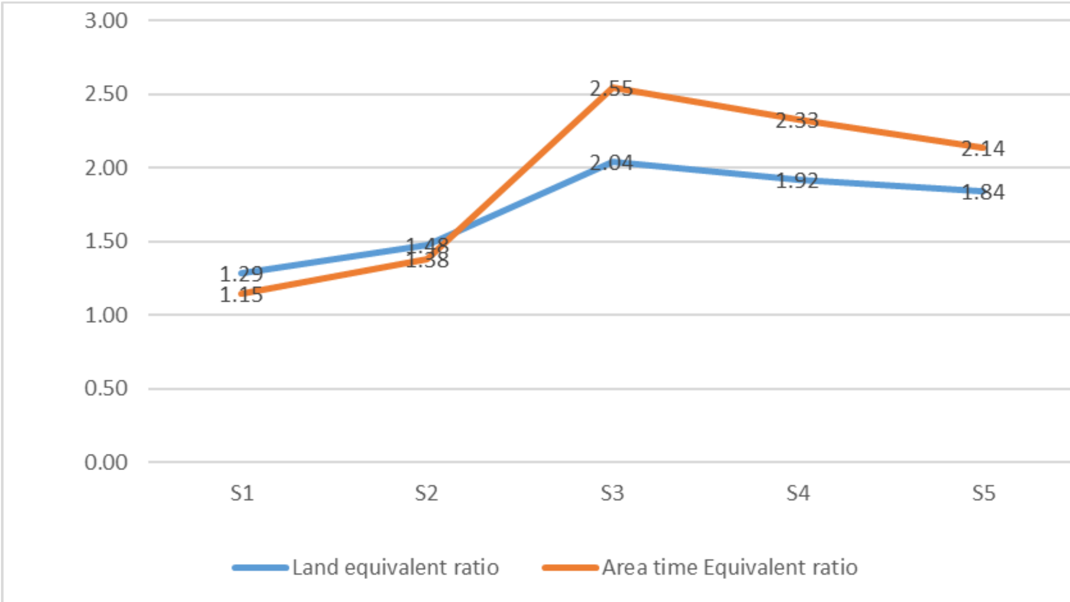

Figure 4. Interaction on land and area time equivalent ratio of upland rice (*Oryza sativa* L.) var. NSIC Rc27 as influenced by time of sowing of mungbean bean (*Vigna radiata* L.) intercrop.

3.7. Yield and Yield Components of Upland rice

Intercropping schemes showed no significant impact on productive tillers and filled and unfilled grains of upland rice (Table 5). However, there were significant differences in upland rice yield. Monocropping of upland rice outperformed intercropping, consistent with Mandal *et al.* (1989), who found higher effective tiller numbers in monocropped rice. Light's crucial role in plant growth, highlighted by Hossain *et al.* (2009) and Feng *et al.* (2019), underscores the need to establish a threshold for sustainable crop production. Notably, in the intercropping system with mungbean (M_3) shading upland rice, there was a decline in upland rice performance, particularly in grain components.

Significant effects of intercropping timing were observed on productive tillers, unfilled grains, and upland rice yield, with the highest mean numbers recorded when mungbean was planted 14 days before upland rice establishment (S_1). This suggests that timing mungbean planting 14 days before upland rice is optimal, leading to improved parameters such as increased productive tillers and filled grains, and reduced unfilled grains compared to other timings. No significant variations were observed in filled grains, and there was no significant interaction effect between different intercropping schemes and timings. This contradicts research by Cagasan and Amarado (2023), who found that simultaneous planting and a 2-week delay after upland rice establishment produced the heaviest panicles. Additionally, Alemayehu *et al.* (2017) and Chemeda (1997) observed greater maize crop height when legume crops were planted simultaneously with maize but found that delayed bean planting led to increased maize grain yield in maize/bean cropping systems.

Analysis of variance revealed significant differences in rice yields among intercropping schemes and based on the timing of mungbean intercropping (Fig. 5). The interaction between intercropping schemes and mungbean sowing time was also significant ($p \leq 0.05$), indicating the importance of both intercropping systems and sowing timing for rice yields. Previous research on rice-cowpea intercropping by Oroka and Omoregie (2007) showed that higher rice densities in cereal-legume intercrops do not substantially decrease grain yield. However, early establishment of mungbean intercropping resulted in the highest yield, contrary to findings by Addo-Quaye *et al.* (2011) that simultaneous planting is necessary for optimal yields of both crops.

Table 5. Productive tillers, number of filled and unfilled grains, and yield of upland rice (*Oryza sativa* L.) var. NSIC Rc27 as influenced by the intercropping scheme and time of sowing of mungbean (*Vigna radiata* L.) intercrop

Treatment	Productive tillers	Filled grains	Unfilled grains	Yield (ton/ha)
Intercropping scheme				
M_1 = Monocropping upland rice	11.76	43.41	62.66	1.45^{a}
M_3 = Intercropping system (upland rice)	7.84	35.54	57.15	1.03^{ab}
Mean	9.81	39.48	59.91	1.24
Time of planting of mungbean intercrop				
S_1	12.62^{a}	50.07	50.36^{bc}	2.03^{a}
S_2	8.48^{bc}	46.40	66.87^{ab}	1.15^{b}
S_3	9.12^{bc}	32.07	66.03^{abc}	1.01^{bc}
S_4	11.18^{ab}	34.85	51.95^{bc}	1.09^{bc}
S_5	7.63^{c}	34.02	64.32^{ab}	0.93^{bc}
Mean	9.80	39.48	59.91	1.24
IS x TPI	ns	ns	ns	**
CV (a) %	28.48	23.18	17.87	18.22
CV (b) %	24.46	30.08	10.81	15.63

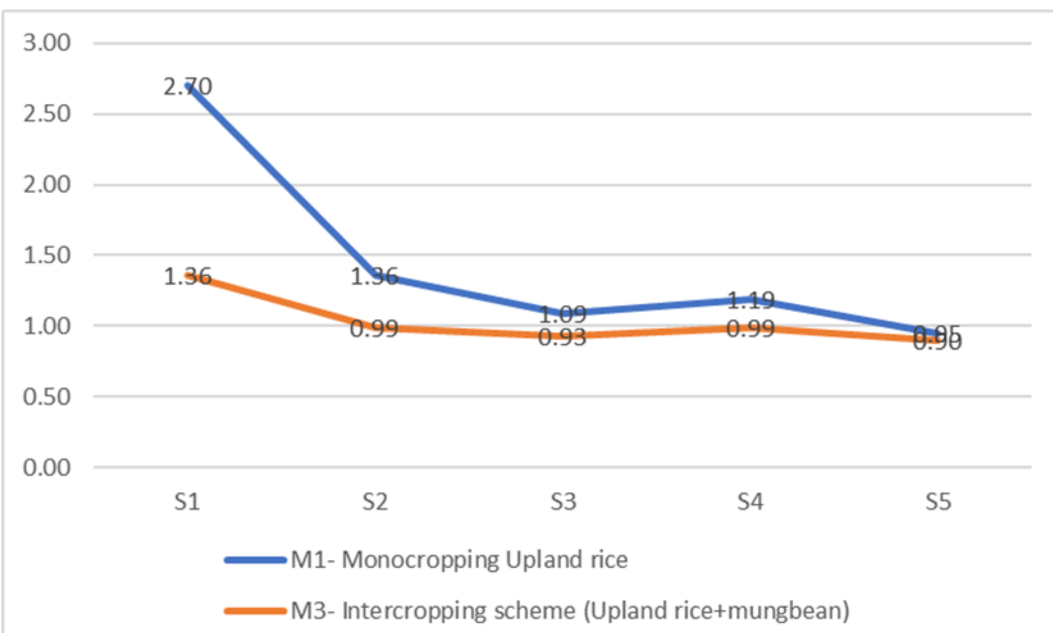

Figure 5. Interaction on the yield of upland rice (*Oryza sativa* L.) var. NSIC Rc27 as influenced by intercropping scheme and time of sowing of mungbean (*Vigna radiata* L.) intercrop

3.8. Yield and yield components of mungbean variety Pag-asa 19

No significant differences were observed in the number of pods per plant and seeds per pod of mungbean (Table 6). However, significant differences were noted in mungbean yield across different intercropping systems. Particularly, mungbean in intercropping system M_3 displayed a higher number of pods per plant and seeds per pod, yielding comparably to monocropping. This aligns with Zhang and Li (2003) findings, which indicated that intercropping tends to yield higher compared to corresponding mono-crops of wheat, maize, or soybean. However, this contrasts with Ghosh's (2004) findings, which reported lower pod yields for groundnut in intercropped plots compared to monoculture plots.

Significant differences were observed in both the number of pods per plant and the overall yield of mungbean, influenced by intercropping timing. Notably, there were no significant variations in the number of seeds per pod. Planting mungbean 14 days before upland rice establishment resulted in the most substantial increase in both the number of pods per plant and overall yield. Additionally, earlier mungbean sowing times, specifically seven and fourteen days before upland rice, led to the highest number of seeds per pod. The advantages of planting mungbean earlier are evident in reduced competition for resources with subsequently planted upland rice, allowing mungbean to allocate more resources towards essential processes like pod formation and seed development.

Table 6. Number of pods, number of seeds per pod, and yield of mungbean as influenced by intercropping scheme and time of sowing of mungbean (*Vigna radiata* L.) intercrop

Treatment	Number of pods per plant	Number of seeds per pod	Yield (ton/ha)
Intercropping scheme			
M_2=Monocropping mungbean	9.90	10.67	2.65[a]
M_3= Intercropping system (mungbean)	10.01	10.90	2.31[ab]
Mean	9.96	10.79	2.48
Time of planting of mungbean intercrop			
S_1	11.77[a]	11.28	3.62[a]
S_2	9.92[abc]	11.62	2.71[bc]
S_3	8.20[c]	10.90	2.54[abc]
S_4	9.02[bc]	9.85	1.85[cd]
S_5	10.88[ab]	10.28	1.70[d]
Mean	9.96	10.79	2.48
IS x TPI	ns	ns	**
CV (a) %	12.39	2.94	27.20
CV (b) %	18.15	9.51	13.31

A statistically significant interaction ($p \leq 0.05$) was observed in mungbean yield, influenced by both intercropping scheme and mungbean sowing timing. Monocropping of upland rice yielded comparable results to the intercropping system (Fig. 6). Planting mungbean 14 days before upland rice establishment (S_1) resulted in the highest mungbean yield. These findings align with Misbahulmunir *et al.* (1989) research, which reported the highest intercrop peanut yield when maize and groundnuts were planted earlier and simultaneously. This parallelism suggests a potential universality in the positive impact of strategic timing on intercropping yield.

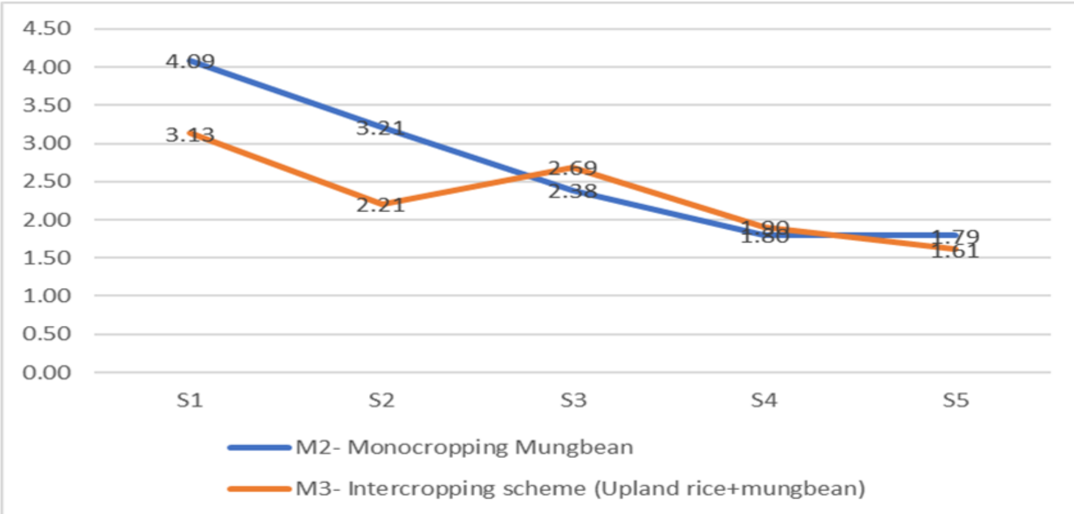

Figure 6. Interaction on the yield of mungbean response as influenced by intercropping scheme and time of sowing of mungbean (*Vigna radiata*) intercrop

3.9. Weed parameters

In the monocropping of upland rice (M_1), the highest weed count was recorded, including various weed species (Table 7). Conversely, treatment under monocropping of mungbean (M_2) and intercropping of upland rice-mungbean (M_3) had fewer weeds due to shading, which limited weed development and created an unfavorable germination environment (Gallon *et al.*, 2018). Significant differences were observed in the weed population affected by the timing of mungbean intercropping, with an interaction effect between the intercropping scheme and mungbean sowing time (Table 7 & Fig. 7). Planting mungbean before upland rice creates conditions favorable for early weed emergence, as weeds utilize sunlight and nutrients before rice establishment. Early mungbean planting stimulates dormant weed seed germination, contributing to a higher weed population.

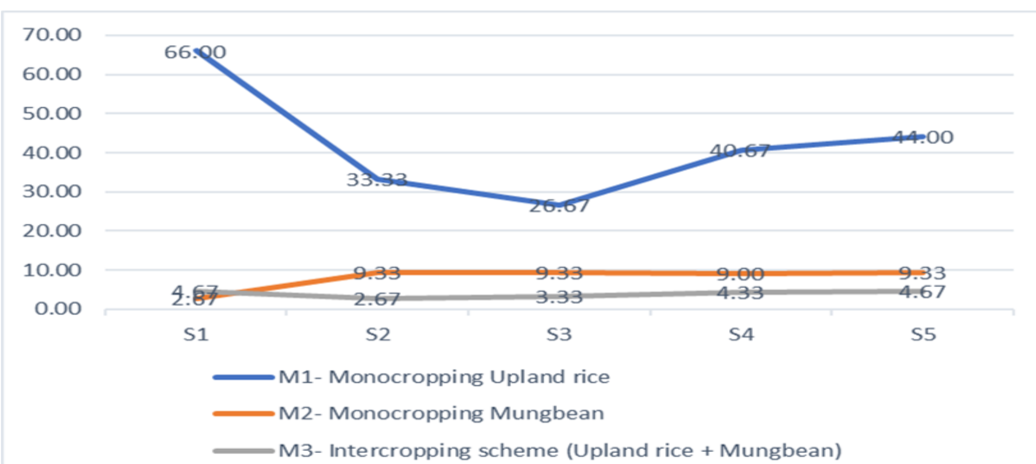

Figure 7. Interaction on the weed population as influenced by intercropping scheme and time of sowing of mungbean (*Vigna radiata*) intercrop

3.9.1. Fresh weight of weeds (kg ha-[1])

Figure 8 displays fresh weed biomass data indicating significant interactions ($p<0.05$) between the intercropping scheme and mungbean sowing times at 60 DAS. Weed-free conditions resulted in substantially lower biomass (9.80 kg ha-[1]) in mono-cropped mungbean compared to weed-infested upland rice (320.93 kg ha-[1]), attributed to upland rice's slower canopy development. Mungbean's faster growth and canopy formation make it more competitive with weeds, reducing biomass. However, some weeds thrive due to upland rice's slower development, allowing more sunlight to reach the soil. Intercropping and simultaneous planting of mungbean exhibit competitiveness in reducing weed biomass compared to monocropping with upland rice.

Mungbean sowing times impact fresh weed biomass, with simultaneous planting yielding the minimum (13.11 kg ha-[1]) and sowing 14 days before main crop establishment producing the maximum (24.11 kg ha-[1]). Monocropping mungbean and simultaneous planting in intercropping demonstrate effectiveness in minimizing weed biomass compared to monocropping upland rice and other mungbean sowing times. Due to wider leaf area and smothering effects, aligning with previous studies on maize-legume intercrops (Rashid *et al.*, 2011; Lelei *et al.*, 2009).

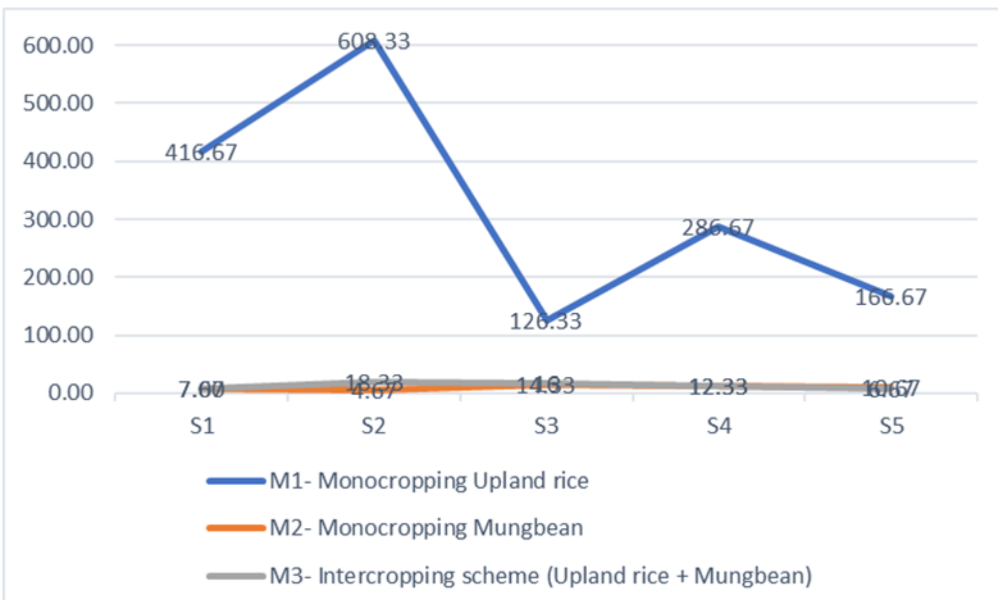

Figure 8. Interaction on the fresh weight of weeds as influenced by intercropping schemes and time of sowing of mungbean (*Vigna radiata*) intercrop

Dry weed biomass, like fresh weed biomass, is significantly influenced by the intercropping system and mungbean sowing time (Table 7), with a significant interaction observed ($p<0.05$) (Fig. 9). Intercropping reduces dry weed biomass in weed-infested plots compared to weed-free plots, with mungbean sowing 14 days before upland rice (S_1) significantly reducing dry weed biomass. Intercropping (M_3) yields the minimum dry weed biomass (2.00 kg ha-[1]) compared to monocropping treatments. Simultaneous planting, particularly in intercropping, contributes to a reduction in dry weed biomass, likely due to substantial canopy coverage provided by mungbean plants, fostering competition against weeds.

In contrast, monocropping upland rice and staggered mungbean sowing in intercropping expose weeds to abundant sunlight, creating favorable conditions for their growth. Varying time of planting in intercropping systems leads to uneven competition or resource availability, allowing weeds to exploit gaps in canopy cover and establish more easily. This highlights the critical role of time in planting in shaping competitive dynamics between crops and weeds in intercropping systems.

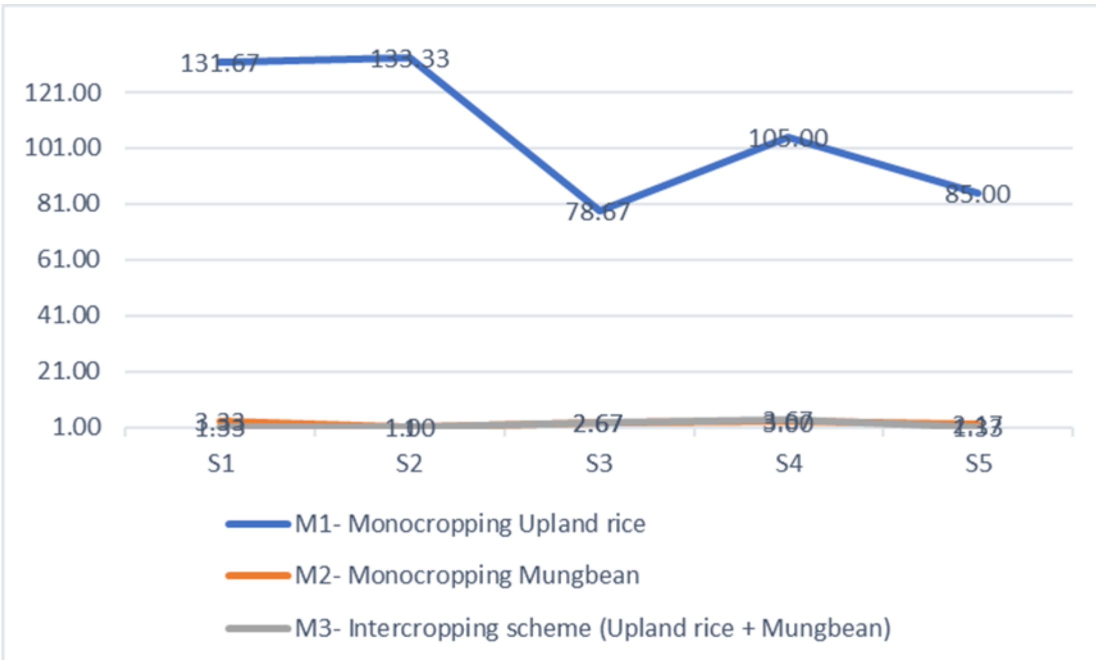

Figure 9. Interaction on the dry weight of weeds as influenced by intercropping scheme and time of sowing of mungbean (*Vigna radiata*) intercrop

Table 7. Weed population, fresh weight of weeds, and dry weight of weeds as influenced by intercropping scheme and time of sowing of mungbean (*Vigna radiata* L.) intercrop

Treatment	Weed population	Fresh weight of weeds	Dry weight of weeds
Intercropping scheme			
M_1 = Monocropping upland rice	41.93^{a}	320.93^{a}	106.73^{a}
M_2 = Monocropping mungbean	7.93^{b}	9.80^{b}	2.43^{b}
M_3 = Intercropping system (Upland rice + Mungbean)	3.93^{b}	12.20^{b}	2.00^{b}
Mean	17.93	114.31	37.05
Time of planting of mungbean intercrop			
S_1	24.11^{a}	143.78^{ab}	45.44^{a}
S_2	15.11^{ac}	210.44^{a}	45.11^{a}
S_3	13.11^{ac}	52.22^{ad}	28.00^{ac}
S_4	18.00^{ab}	103.78^{ac}	37.22^{ab}
S_5	19.33^{ab}	61.34^{ad}	29.50^{ac}
Mean	17.93	114.31	37.05
IS x TPI	**	**	**
CV (a) %	29.33	28.45	32.42
CV (b) %	23.96	25.36	28.41

3.10. Cost and return analysis

The cost and return analysis on upland rice and mungbean under different cropping systems are reflected in Tables 9 and 10, respectively, considering various intercropping schemes and mungbean sowing time as the variables of this undertaking.

For upland rice, the monocropping scheme outperformed the intercropping scheme in gross income (Table 9). However, an exception was observed with different mungbean sowing times. Optimal results were achieved when mungbean was planted 14 days before upland rice establishment (S_1), yielding the highest gross income (PhP111,650), net income (PhP70,325.00), and an impressive return on investment (ROI) of 170.18 %. Conversely, the least favorable outcomes were observed when mungbean was planted 14 days after upland rice establishment (S_5).

These findings diverge from earlier reports suggesting a yield advantage in crop mixtures over monoculture for upland rice (Ahmed *et al.*, 2011). However, they align with the conclusion of Boakye-Achampong (2017), which indicated a decline in grain yield with increasing intercropping intensity. Islam *et al.* (1993) specifically highlighted the susceptibility of mungbean to competition from maize in this intercropping system, attributing reduced yield to the perceived impact of light competition as the primary limiting factor.

Table 8. Profit cost and return analysis of upland rice (*Oryza sativa* L.) NSIC Rc27 variety as influenced by the intercropping scheme and time of sowing of mungbean (*Vigna radiata* L.) intercrop

Treatment	Yield (ton ha^{-1})	Gross income (PhP ha $^{-1}$)	Total variable cost (PhP ha^{-1})	Net profit (PhP)	ROI (%)
Intercropping scheme					
M_1 = Monocropping Upland rice	1.45	79,750.00	41,325.00	38,425.00	92.98
M_3 =Intercropping system (Upland rice)	1.03	56,650.00	41.325.00	15,325.00	37.08
Mean	1.24	68,200.00	41,325.00	28,875.00	69.87
Time of planting of mungbean intercrop					
S_1	2.03	111,650.00	41.325.00	70,325.00	170.18
S_2	1.15	63,250.00	41.325.00	21,925.00	53.05
S_3	1.01	55,550.00	41,325.00	14,225.00	34.42
S_4	1.09	59,950.00	41,325.00	18,625.00	45.07
S_5	0.93	51,150.00	41,325.00	9,825.00	23.77
Mean	1.24	68,310.00	41,325.00	26,985.00	65.30

The gross profit is based on the farm gate price of PhP 55.00 per kilogram

On the cost analysis of mungbean, monocropping mungbean demonstrated a higher gross income of PhP238,500.00 (Table 10). Remarkably, planting mungbean 14 days before upland rice establishment (M_1) again yielded the most favorable results, with the highest gross income (PhP324,900.00), net income (PhP283,575.00), and an exceptional ROI of 686.21%. Conversely, the least favorable outcomes were noted when mungbean was sown seven days after upland rice establishment.

Table 9. Profit cost and return analysis of mungbean as influenced by intercropping schemes and time of sowing of mungbean (*Vigna radiata* L.) intercrop.

Treatment	Yield (ton ha^{-1})	Gross income (PhP ha $^{-1}$)	Total variable cost (PhP ha^{-1})	Net profit (PhP)	ROI (%)
Intercropping scheme					
M_2 = Sole cropping Mungbean	2.65	238,500.00	41,325.00	197,175.00	477.13
M_3=Intercropping system (Mungbean)	2.31	207,900.00	41.325.00	166,575.00	403.09
Mean	2.48	119,250.00	41,325.00	181,875.00	440.19
Time of planting of mungbean intercrop					
S_1	3.61	324,900.00	41.325.00	283,575.00	686.21
S_2	2.71	243,900.00	41.325.00	202,575.00	490.20
S_3	2.54	228,600.00	41,325.00	187,275.00	453.18
S_4	1.85	166,500.00	41,325.00	125,175.00	308.96
S_5	1.70	153,000.00	41,325.00	111,675.00	270.24
Mean	2.48	223,380.00	41,325.00	182,055.00	441.76

The gross profit is based on the farm gate price of PhP 90.00 per kilogram.

4. Conclusion

Intercropping upland rice with mungbean showed minimal impact on most agronomic characteristics and yield components of both crops. However, significant differences were observed in flowering time, maturity, and yield, with optimal results when mungbean was planted 14 days before upland rice establishment. Mungbean planting time also affected its characteristics, with early planting leading to earlier flowering and maturity. All intercropping arrangements showed land and area-time equivalence, indicating compatibility. Interaction effects between the intercropping scheme and mungbean sowing time were noted, especially in flowering, maturity, and weed parameters. Monocropping and mungbean planted two weeks before upland rice establishment resulted in a slightly higher gross profit.

Recommendations

Planting mungbean two weeks before upland rice establishment is recommended. Further research on diverse varieties of both crops in intercropping systems is necessary. Validation in different locations is essential. On-farm demonstrations should be conducted where intercropping is applicable.

Acknowledgment

Gratitude is extended to all who contributed to this research. Special thanks to the Living God for guidance and blessings. The author acknowledges the invaluable support of Dr. Dionesio M. Baňoc, thesis adviser, and committee members Prof. Luz G. Asio and Dr. Karen Luz M. Yap. My utmost appreciation is also extended to the Office of the Graduate School, DOST-ASTHRDP program, Department of Agronomy, family, friends, and individuals who assisted in various capacities. All praise to God!

Declaration

The authors declare no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

5. References

Adekiya, A.O., Agbede, T.M. (2017). 'Effect of methods and time of poultry manure application on soil and leaf nutrient concentrations, growth, and fruit yield of tomato (*Lycopersicon esculentum* Mill)'. *Journal of the Saudi Society of Agricultural Sciences.* 16 (4):383-388.

Addo-Quaye, A.A., Darkwa, A.A., Ocloo, G.K. (2011). 'Yield and productivity of component crops in a maize-soybean intercropping system as affected by time of planting and spatial arrangement'. *ARPN J. Agric. Biol. Sci.* 6(9): 50-57.

Ahmed, F., Islam, M.N.,Alom, M.S.,Sarker,M.A.A., Mannaf M.A. (2011). 'Study on intercropping leafy vegetables with okra (*Abelmoschus esculentus* l.). *Bangladesh J. Agril. Res.* 38(1): 137-143

Alemayehu, D., Shumi, D., Afeta, T. (2017). 'Effect of Variety and Time of Intercropping of Common Bean (*Phaseolus vulgaris* L.) With Maize (*Zea mays* L.) on Yield Components and Yields of Associated Crops and Productivity of the System at Mid-Land of Guji, Southern Ethiopia'. Adv Crop Sci Tech 6: 324. doi:10.4172/2329-8863.1000324

Alogaidi, F., Al-Shugeairy, Z.K., Hadi, B.H., Hassan, W.A. (2019). 'Effect of planting distance on yield and yield components of four introduced upland rice varieties under aerobic conditions'. Department of Field Crops, College of Agricultural Engineering Sciences, University of Baghdad, Iraq. 19 (1): 699-607.

Andersen, M.K., Hauggaard-Nielsen, H., Ambus, P., Jensen, E.S. (2004). 'Biomass production, symbiotic nitrogen fixation, and inorganic N use in dual and tri-component annual intercrops'. Plant and Soil, 266: 273-287.

Boakye-Achampong, S., Ohene-Yankyera, K., Aidoo, R., Sørensen, O.J. (2017). 'Is there any economics in smallholder cocoyam production? Evidence from the forest agroecological zone of Ghana'. Agric & Food Secure 6, 44 (2017). https://doi.org/10.1186/s40066-017-0121-9.

Cagasan, U., Amarado, J. (2023). 'Influence of Intercropping on the Growth and Yield Performance of Upland Rice (*Oryza sativa* L. var. Zambales) and Peanut (*Arachis hypogaea* L.)'. *Research in Agricultural Sciences*, 54(1), 2-8.

Chemeda, F. (1997). 'Effects of planting pattern, relative planting date and intra-row spacing on a haricot bean/maize intercrop'. *African Crop Science Journal*, 5(1): 15-22. Ciampitti, I.A., Vyn, T.J. (2011). 'A comprehensive study of plant density consequences on nitrogen uptake dynamics of maize plants from vegetative to reproductive stages'. *Field Crops Res*. 121, 2–18. doi: 10.1016/j.fcr.2010.10.009.

Craine, J., Dybzinski, R. (2013). 'Mechanisms of plant competition for nutrients, water, and Light'. https://doi.org/10.1111/1365-2435.12081.

Favero, V.O., Carvalho, R.H, Motta, V.M., Leite, A.B.C., Coelho, M.R.R., Xavier, G.R., Rumjanek, N.G., Urquiaga, S. (2021). 'Bradyrhizobium is the only rhizobial inhabitant of mung bean (*Vigna radiata*) nodules in tropical soils: A strategy based on the microbiome for improving biological nitrogen fixation using bio-products'. Front. Plant Sci. 2021, 11, 2186. [Google Scholar] [CrossRef].

Feng, L., Raza, M.A., Li, Z., Chen, Y., Khalid, M.H., Du, B., Yang, F. (2019). 'The influence of light intensity and leaf movement on photosynthesis characteristics and carbon balance of soybean'. Frontiers in plant science, 9, 1952.

Fischer, R.A. (1975). 'Yield Potential in Dwarf Spring Wheat and the Effect of Shading'. Crop Science, 15: 607-613.

Gallon, M., Trezzi, M.M., Diesel, F., Balbinot, A.A., Pagnoncelli, F.D.B., Barancelli, M.V.J. (2018). 'Environmental factors' action on the germination process and initial growth of weeds of the Rubiaceae family'. *South African Journal of Botany*. Volume 117, July 2018, Pages 26-33. https://doi.org/10.1016/j.sajb.2018.04.009

Ghosh, P.K. (2004). 'Growth, yield, competition, and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India'. *Field Crops Research*, Volume, 88, Issues2–3, Pages227-237, ISSN0378-4290, https://doi.org/10.1016/j.fcr.2004.01.015.

Gupta, P.C., O'Toole J.C. (1986). 'Upland rice, A Global Perspective. *International Rice Research Institute*, Los Baños, Laguna, Philippines.

Grzyb, A., Wolna-Maruwka A., Niewiadomska, A. (2021). 'The Significance of Microbial Transformation of Nitrogen Compounds in the Light of Integrated Crop Management'. Agronomy. 11(7):1415. https://doi.org/10.3390/agronomy11071415.

Gworek, B., Łabętowicz, J., Kijeńska, M., Tokarz, L., Barański, A. (2021). 'Nitrogen transformations from nitrogen fertilizers in soils of central and eastern Europe in changing climatic conditions'. Soil Science Annual, 72(1), 132440. https://doi.org/10.37501/soilsa/132440.

Hossain, A., Akamine, M., Ishimine, H., Teruya, Y., Aniya, R., Yamawaki. (2009). 'Effects of relative light intensity on the growth, yield, and curcumin content of turmeric (*Curcuma longa* L.) in Okinawa, Japan'. Plant production science, 12(1), 29-36.

Huss, C.P., Holmes, K.D., Blubaugh, C.K. (2022). 'Benefits and Risks of Intercropping for Crop Resilience and Pest Management'. *Journal of Economic Entomology*, Volume 115,Issue 5, October 2022, Pages 1350–1362, https://doi.org/10.1093/jee/toac045.

Islam, S. M. T., Kubota F., Mollah M.F.H.,Agata W. (1993). 'Effect of Shading on the Growth and Yield of Mungbean (*Vigna radiata* L. Wilczek*)'. J. Agron. Crop Sci*. 171: 274–278.

Lelei, J.J., Onwonga, R.N., Freyer, B. (2009). 'Organic based nutrient management strategies: effect on soil nutrient availability and maize performance in Njoro, Kenya'. *Afric. J. Agric. Res.*, 4(2): 92-99.

Li, C., Hoffland, E., Kuyper, T.W., Yu, Y., Li, H., Zhang, C., Zhang, F., Van der Werf. (2020). 'Yield gain, complementarity and competitive dominance in intercropping in China: a meta-analysis of drivers of yield gain using additive partitioning'. *European J. Agron*. 113: 12598.

Manasa, P., Maitra S., Reddy M.D. (2018). 'Effect of Summer maize-legume intercropping system on growth, productivity, and competitive ability of crops'. *Int. J. Manag. Technol. Eng.* 8, 2871–2875. [Google Scholar].

Mandal, B.K., Dhara, M.C., Mandal, B.B., Das, S.K., Nandy, R. (1989). 'Effect of Intercropping on the Yield Components of Rice, Mungbean, Soybean, Peanut, and Blackgram'. https://doi.org/10.1111/j.1439-037X.1989.tb00684.x. Volume162, Issue1. Pages 30-34.

Mandal, B., Dhara, M., Mandal, B., Das, S., Nandy, R. (1990). 'Rice, Mungbean, Soybean, Peanut, Ricebean, and Blackgram Yields under Different Intercropping Systems'. https://doi.org/10.2134/agronj1990.00021962008200060006. *Agronomy Journal*, vol. 82, issue 6, pp. 1063-1066.

Marler, T. (1994). 'Developmental Light Level Effect of Growth, Morphology and Leaf Physiology of Young Carambola Trees'. *Journal American Society of Horticulture Science*, 199(4): 711-718.

Misbahulmunir, M.Y., Sammons, D.J., Weil, P.R. (1989). 'Corn-peanut intercrop performance
about component crop relative planting dates'. *Agronomy Journal* 81:184-189.

Nouri, M., Reddy, K.C. (1991). 'Water use of millet and cowpea in association and sole crop. (In French). In: Proceedings International workshop on Soil Water Balance in the Sudano-Sahelian Zone. Sivakumar, M.V.K., Wallace, J.S., Renard, C. and Giroux, C.(Eds.), pp. 421-429. Niamey, Niger, 18-23 Feb. 1991. IAHS Publ. 199.

Olsen, J., Weiner J. (2007). 'The influence of *Triticum aestivum* density, sowing pattern, and nitrogen fertilization on leaf area index and its spatial variation'. Basic Appl. Ecol. 8:252–257.

Oroka, F.O., Omoregie, A.U. (2007). 'Competition in rice-cowpea intercrops is affected by nitrogen fertilization and plant population'. Scientia Agricola (Piracicaba, Braz), 64, 621-629.

Price, C., Munns, R. (2016). 'Growth analysis: a quantitative approach'. School of Plant Biology, University of Western Australia, 2 CSIRO Agriculture, Canberra.

Rafiuddin, Mollah A., Risal M., Musa Y., Yassi A., Dachlan A. (2021). 'Growth and production of paddy rice (*Oryza sativa* L.) in various planting systems and types of liquid organic fertilizers'. Department of Agronomy, Faculty of Agriculture, Hasanuddin University, Jl. Perintis. DOI 10.1088/1755-1315/807/4/042055.

Rao, A.A.N., Wani S.P., Ramesha M.S., Ladha J.K. (2017). 'Rice Production System'. ICRISAT Development Center (IDC) and International Rice Research Institute (IRRI), International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru502 324, India.

Rashid, S., Ahmed, Z.I., Ashraf, M., Arif, M., Malik, M.A., Munir, M., Khan, M.A. (2011).'Response of maize-legume intercropping system to different fertility sources under rainfed conditions'. *Sarhad J. Agric*., 27(4): 503-511.

Rasmussen, A., Schmidt, S. (2022). '4.1-Nutrient requirements and root architecture'. Centre for Plant Integrative Biology, University of Nottingham, UK; 2 School of Agriculture and Food Science, University of Queensland.

Rossini, M.A, Maddonni, G.A., Otegui, M.E.(2011). 'Inter-plant competition for resources in maize crops grown under contrasting nitrogen supply and density: Variability in plant and ear growth'. *Field Crops Res*. 121, 373–380. doi: 10.1016/j.fcr.2011.01.003

Saeed, M., Shahid, M.R.M., Jabbar, A., Ullah, E., Khan, M.B. (1999). 'Agro-economic studies of cotton-based inter/relay cropping system'. *Int J Agric Biol* 4:234–237.

Xiao S., Chen S.Y., Zhao L.Q., Wang G. (2006). 'Density Effects on Plant Height Growth and Inequality in Sunflower Populations'. *Journal of Integrative Plant Biology* 48: 513-519.

Saban, Y.,Mehmt A.,Mustafa E.(2007). 'Identification of Advantages of Maize Legume Intercropping over Solitary Copping through Competition Indices in the East Mediterranean Region'. *Turk Journal Agriculture* 32: 111–119.

Setiawan, A.N. (2022). 'Microclimate Dynamics in Sweet Corn Intercropping with Various Legumes' IOP Conf. Ser.: Earth Environ. Sci. 985 012013.

Tsay, J.S., Fukai, S., Wilson, G.L. (1998). 'Effects of relative sowing time of soybean on growth and yield of cassava in cassava/soybean intercropping'. *Field Crops Research*, Volume 19, Issue 3,1988, Pages 227-239, ISSN 0378-4290, https://doi.org/10.1016/0378-4290(88)90045-7.

Vandermeer, J. (1989). 'The Ecology of Intercropping'. Cambridge University Press, Cambridge, 237 p. https://doi.org/10.1017/CBO9780511623523.

Worku, W. (2014). 'Sequential intercropping of common bean and mung bean with maize in southern Ethiopia'. Experimental Agriculture, Vol. 50(1):90-108.

Yang, F., Sun, Y., Fang, H., Yao, Z., Zhang, J., Zhu, Y., Song, K., Wang, Z., Hu, M. (2012). 'Comparison of different methods for corn LAI estimation over northeastern China'. *International Journal of Applied Earth Observation and Geoinformation*, 18: 466–471.

Zhang, F., Li, L. (2003). 'Using competitive and facilitative interactions in intercropping systems enhance crop productivity and nutrient-use efficiency'. Plant and Soil 248, 305–312. https://doi.org/10.1023/A:1022352229863.